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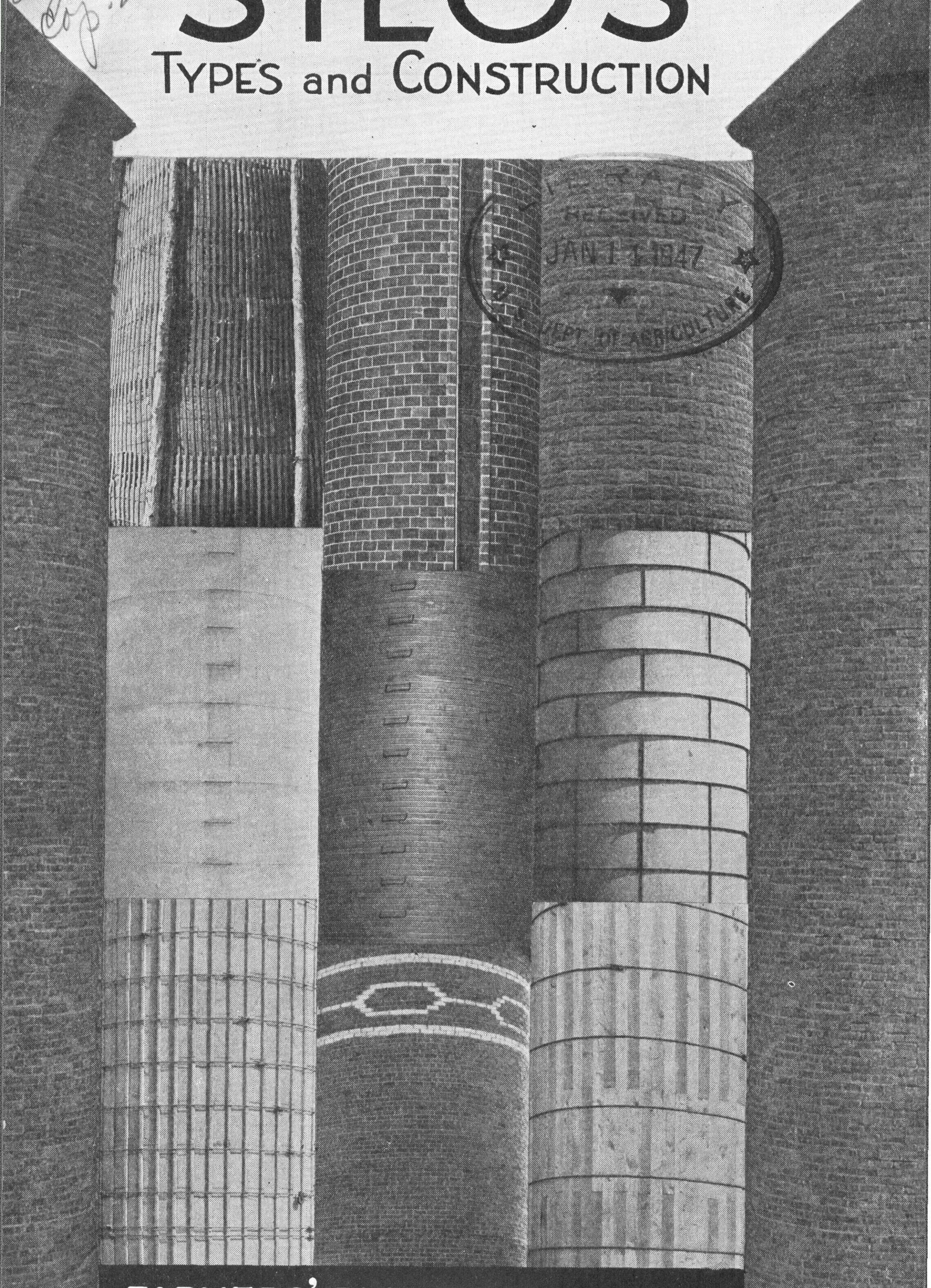
SILOS

TYPES and CONSTRUCTION



FARMERS' BULLETIN No. 1820

U. S. DEPARTMENT OF AGRICULTURE

GAS DANGER IN SILOS

Suffocating gas from fermenting silage, mostly carbon dioxide, forms in all silos shortly after filling begins and continues until fermentation stops. The gas, being heavier than air, collects and remains in any depression or enclosed space when there is not a strong, free movement of air or the air in the silo is no longer agitated. The above-ground silo, while not free from gas danger, offers better ventilation through its doors, and large quantities seldom accumulate unless the doors are put in too far above the silage level. Gas is a particular hazard in the below-ground silo. Many lives are lost each year because of carelessness in entering a silo where there may be danger of gas. During the filling period the blower on the silage cutter should be run several minutes before anyone enters a silo, and, in the case of a deep pit or any silo into which the distributor pipe does not extend far enough to thoroughly agitate the air, a lighted lantern should be lowered to the bottom to test the air. If the lantern continues to burn, it is safe to enter the silo. If the lantern goes out do not enter until the air can be stirred to dilute the gas by lowering a basket on a rope and lifting and dropping it a number of times or with a blanket, large piece of canvas, or with a tree branch.

A victim of silo gas suffers from lack of oxygen and should be moved into fresh air as soon as possible and artificial respiration applied. Before a rescuer enters the silo a rope should be tied securely to him in case it may be necessary to pull him out. Artificial respiration may be applied by placing the suffocating person prone, with the head to one side, and alternately applying and releasing pressure on the back in the region of the lower ribs, 12 to 15 times each minute. Send for a physician, but in the meantime do not relax efforts to restore breathing.

This bulletin supersedes Farmers' Bulletins No. 825, Pit Silos, and No. 855, Home-Made Silos.

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SILO TYPES AND CONSTRUCTION

By J. R. McCalmont, *agricultural engineer, Division of Agricultural Engineering, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

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INTRODUCTION

IN A LITTLE MORE than 50 years the silo has become one of the conspicuous buildings of the rural landscape in many parts of the country and is to be found in every State. It has been an important factor in solving the livestock feeding problem, particularly in milk and beef production. Silage is also much used as a feed for sheep and to some extent for horses and mules.[1]

Not all farmers can use silos to advantage, but permanent, upright silos are practical where there is a herd of as many as 10 dairy cows or the equivalent in other livestock for which silage is a good feed. With a smaller number than this the investment in the silo and the machinery needed for filling it generally makes overhead costs too high per animal; also, it is not usually feasible to build a permanent silo small enough so that when few animals are fed the silage will be taken down fast enough to avoid spoilage.

TYPES OF SILOS AND THEIR SELECTION

The kind of silo to build depends upon the investment warranted and the durability desired. In choosing the type several factors must be considered, chief of which are the service requirements, the cash and time available, first cost, upkeep, and durability.

The farmer is the best judge of his service requirements and will determine whether the need for a silo is temporary or permanent, urgent or ordinary, and the availability of cash, labor, and materials. If he is a tenant rather than an owner, a portable or low-cost temporary-type silo may be considered. The farmer in either case is interested in obtaining the most efficient feed storage in keeping with his needs at the least cost.

[1] See Farmers' Bulletin 578, The Making and Feeding of Silage.

Silos may be divided roughly into above-ground—tower or upright—and the below-ground—pit or trench—silo, either of which may be built for temporary or continued use.

Brick, tile, and concrete silos, when well-built and made of good materials, have the advantage of attractiveness, durability, and fire and wind resistance. Brick and tile are commonly used in regions where ceramic products are readily available or may be shipped in at reasonable cost. Brick are less frequently used than some of the other materials because of the high labor cost incurred in erecting them. This extra cost is sometimes offset by the use of second-grade paving bricks. Because of the action of silage acids on mortar, particular attention must be given to joints.

Well-made concrete silos require little attention except for an occasional coat of paint on the walls. Careful workmanship and the selection of good-quality materials for concrete pay good dividends in lower upkeep costs whether the concrete is in the form of blocks, staves, or monolithic walls. The blocks are least desirable because the quality in many cases is not good enough for this purpose. Concrete staves of good quality are convenient to use as they may be quickly erected without forms, which are required for the monolithic type; however, in many cases sand and gravel are readily available, and the farmer may find it most economical, in spite of the cost of forms and the greater quantity of material, to build the monolithic type.

Of the many types of wood silos, the most common is built of milled staves, the life of which varies with the kind of wood and its treatment. The less-durable woods are creosoted. Such silos require hoops or bands, which must be loosened at filling time to avoid crushing the staves by swelling and should be tightened when the silo is empty to avoid collapse when the silo dries out. Such silos may be troublesome if these precautions are neglected. Other forms of wood silos are discussed later and can be built at relatively low first cost, if farm labor and local materials are used. The life of such silos may be relatively shorter than that of silos built of more durable materials, but very satisfactory service may be obtained if they are carefully built in accordance with the directions given in this bulletin.

A metal silo is relatively easy to erect and, if rust resistant and kept painted, it is durable. Naturally, it is fireproof, but may buckle and be badly damaged by a fire near it. In regions of heavy winds it needs firm anchorage, particularly when empty. Costs vary with the gage and kind of metal and with freight rates.

One of the temporary types may be used in an emergency such as that brought about by drought, destruction of buildings by fire, or some other unforeseen circumstance. They are sometimes used in place of more durable silos when sufficient money is not available to build a more substantial structure. It must be remembered that the percentage of spoilage in these silos is higher than in the more substantial structures.

ABOVE-GROUND PERMANENT SILOS

GENERAL

To provide for low depreciation and to keep down spoilage of silage, the above-ground silo must have certain construction features.

CONSTRUCTION REQUIREMENTS

1. The walls should be airtight. In wood silos lumber should be well matched and contain no large knots. Doors must fit tightly.
2. Walls should be smooth and plumb and circular in form for structural strength and to permit free settling and packing of silage to avoid air pockets. Square, hexagonal, or octagonal silos are sometimes made when farm-cut lumber is used, but are not recommended.
3. Walls should withstand considerable lateral strain without cracking or bulging. Lateral pressures increase directly with the depth of silage and vary with the kind of silage stored. The deeper the silage the greater the average capacity per foot of depth. The higher the pressure the more air is squeezed out and the less spoilage.
4. Exterior wall surfaces should be protected where necessary to retard weathering or decay.
5. The foundation must be well drained and of ample size and strength to support the load and to avoid uneven settlement and cracking of the walls.
6. The silo should have a chute to facilitate feeding, and a safe ladder giving access to the filling door.
7. A roof is desirable in regions of heavy snow or rain or extreme cold.

LOCATION

Most commonly on dairy farms an upright silo is located a few feet from the barn and is connected with a separate feed room; the barn door can then be closed at milking time and the silage odors kept out. Where silage is fed to beef cattle the silo is often placed away from other buildings but handy to the feed lots. The bottom of the silo should not be more than 5 feet below the lowest door.

SIZE AND CAPACITY

The correct diameter of the silo depends upon the quantity of silage to be fed daily. The silage should be removed at the rate of 2 to 3 inches a day, depending upon the air temperature. The warmer the weather the more must be removed daily to prevent spoilage. In winter probably 2 inches a day should be removed (table 1). A common error in building is to make the diameter too large for the size of the herd. If the herd is reduced in size to a point where the low consumption results in spoilage when silage is fed off the entire surface, the losses may be reduced by feeding off to a depth of 1 to 2 feet on alternate halves. When silage is needed for large herds, several silos are generally built. This practice allows different crops to be ensiled and fed either separately or together.

TABLE 1.—*Relation of size of herd to diameter of silo for winter feeding, on the basis of 40 pounds of silage per cubic foot and the removal of 2 inches of silage daily to avoid spoilage*

Inside diameter of silo (feet)	Volume per foot of depth	Amount to be removed—			Animals that may be fed with a daily allowance per head of—			
		Daily	For a feeding period of—					
			180 days	240 days	40 pounds	30 pounds	20 pounds	15 pounds
	Cubic feet	*Pounds*	*Tons*	*Tons*	*Number*	*Number*	*Number*	*Number*
10	78.5	524	47	63	13	17	26	35
11	95.0	634	57	76	16	21	31	42
12	113.1	754	68	90	19	25	37	50
13	132.7	885	80	106	22	29	44	59
14	153.9	1,027	92	123	25	34	51	68
15	176.7	1,178	106	141	29	39	59	78
16	201.0	1,340	120	161	33	44	67	89
17	227.0	1,513	136	182	38	50	75	101
18	254.5	1,696	153	203	42	56	85	113
20	314.2	2,094	188	251	52	70	104	139

The weight of a cubic foot of silage varies (see table 4) with depth in the silo, rate of filling, length of cut, maturity of material, and moisture content. Corn silage, put up when about 75 percent of the grain has passed the milk stage and containing approximately 70 percent moisture, is considered normal silage. Knowing the quantity of silage to be fed daily, it is possible to estimate the diameter of the silo necessary to permit the removal of a certain depth each day. Table 1 shows the proper diameter of the silo for herds of different sizes for winter feeding, when a 2-inch depth of silage is to be removed daily.

A 900-pound cow ordinarily eats 30 pounds of silage a day and a 1,200 pound cow about 40 pounds. Yearlings eat about half as much as mature animals; fattening cattle, 25 to 35 pounds for each 1,000 pounds live weight. A sheep takes about one-eighth as much as a cow, and work horses should be limited to 15 or 20 pounds daily. Particular care should be taken to avoid feeding moldly silage to horses.

The practice of using silage instead of soiling crops to supplement pastures during summer droughts and in the early fall is becoming common. For such feeding the daily ration for each cow may be as low as 10 pounds, depending upon the amount and quality of pasture or other succulent feeds available. For the same herd the silo for summer feeding should be of smaller diameter than the one used for winter feeding, since 3 inches instead of 2 are to be removed daily. To provide for summer feeding of small herds an additional silo of smaller diameter is desirable. Table 2 shows the relation between the size of the herd and the diameter of the silo when 3 inches of silage is removed daily.

TABLE 2.—*Relation of size of herd to diameter of silo for summer feeding, on the basis of 40 pounds of silage per cubic foot and the removal of 3 inches of silage daily to avoid spoilage*

Inside diameter of silo (feet)	Volume per foot of depth	Amount to be removed—				Animals that may be fed with a daily allowance per head of—			
		Daily	For a feeding period of—						
			30 days	45 days	60 days	30 pounds	20 pounds	15 pounds	10 pounds
	Cubic feet	*Pounds*	*Tons*	*Tons*	*Tons*	*Number*	*Number*	*Number*	*Number*
10	78.5	785	12	18	24	26	39	52	78
11	95.0	950	14	21	28	31	47	63	95
12	113.1	1,131	17	25	34	38	56	75	113
13	132.7	1,327	20	30	40	44	66	88	132
14	153.9	1,539	23	35	46	51	77	102	154
15	176.7	1,767	27	40	54	59	88	118	177
16	201.0	2,010	30	45	60	67	100	134	201

In general the height of the silo should not be less than twice nor more than three and one-half times the diameter. The greater the depth the better the quality of silage and the greater the unit capacity. Extreme heights should be avoided because of the excessive power required to elevate the cut corn.

Table 3, based on the average weights of silage actually placed in five silos at the Department's Research Center at Beltsville, Md., over a period of several years, indicates the required depth of the silo. For example, a herd of 25 cows fed 30 pounds per head daily for a period of 240 days will need 90 tons of silage (table 1) and will require a silo 12 to 14 feet in diameter. Table 3 shows that, with some allowance for loss by waste and spoilage, a 12- by 38-foot or a 14- by 30-foot silo will be satisfactory for this herd.

TABLE 3.—*Capacity of silos with different diameters and depths of silage*[1]

Depth of silage (feet)	Capacity with an inside diameter of—										
	10 feet	11 feet	12 feet	13 feet	14 feet	15 feet	16 feet	17 feet	18 feet	19 feet	20 feet
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
20	27										
22	30	37									
24	34	41	49								
26	38	46	55	65							
28	43	52	61	72	84						
30	47	57	68	80	92	106	121				
32	51	62	74	87	100	115	131	148			
34	56	67	80	94	109	125	142	161	180		
36		73	86	101	117	135	153	173	194	216	
38			93	109	126	145	165	186	209	233	258
40			100	117	135	155	177	200	224	249	276
42				124	144	165	188	212	237	264	293
44					152	174	198	224	251	279	310
46						184	209	236	265	295	327
48							220	248	279	310	344
50								261	293	326	361

[1] Capacities given are for normal corn silage when the silo is filled at the average speed of 20 to 50 tons per day with 1 man in the silo and refilled once after silage has settled.

A farmer may wish to know approximately the amount of silage in a partially emptied silo. Tables can give only a rough estimate as a substitute for weighing since unit weight of silage is affected by many

factors. However, table 4, based on the weight of well-settled silage, permits the making of such an estimate. For example, if a 14- by 45-foot silo contains 40 feet of settled silage and 20 feet has been removed, more than half of the silage by weight remains because the lower 20 feet is more compact than the upper 20 feet. The volume of 1 foot of depth of silage is found from table 1 to be 153.9 cubic feet. Table 4 gives the average weights of silage as 34.9 and 47.0 pounds per cubic foot at 20 and 40 feet, respectively; $40 \times 153.9 \times 47 = 289{,}332$ pounds in the silo before feeding started. Subtracting the silage removed from the upper 20 feet—$20 \times 153.9 \times 34.9 = 107{,}422$, leaves 181,910 pounds, or about 91 tons.

TABLE 4.—*Weight of settled silage per cubic foot at a given depth and the average weight to that depth when the silo is full*

Depth of settled silage (feet)	Weight per cubic foot at given depth	Average weight per cubic foot	Depth of settled silage (feet)	Weight per cubic foot at given depth	Average weight per cubic foot	Depth of settled silage (feet)	Weight per cubic foot at given depth	Average weight per cubic foot
	Pounds	*Pounds*		*Pounds*	*Pounds*		*Pounds*	*Pounds*
1	18.5	18.5	15	42.0	31.3	28	57	40.2
2	20.8	19.7	16	43	32.1	29	58	40.8
3	23.0	20.8	17	44.5	32.8	30	59	41.4
4	24.9	21.8	18	45.8	33.5	31	60	42.0
5	26.8	22.8	19	47	34.2	32	60.9	42.7
6	28.5	23.8	20	48.1	34.9	33	61.9	43.2
7	30.2	24.7	21	49.4	35.6	34	62.8	43.7
8	31.8	25.6	22	50.5	36.3	35	63.5	44.3
9	33.5	26.4	23	51.6	36.9	36	64.3	44.9
10	35	27.3	24	52.5	37.6	37	65.1	45.4
11	36.5	28.1	25	54	38.2	38	65.9	45.9
12	38	28.9	26	55.0	38.9	39	66.6	46.5
13	39.5	29.8	27	56	39.5	40	67.4	47.0
14	40.8	30.6						

The sale price of silage often may be based on its equivalent feeding value with respect to corn and hay. A ton of silage in Illinois ordinarily contains 4.6 bushels of grain, and the stalks and leaves approximate a value of 270 pounds of mixed hay. The feeding value of the silage is about one-third of the value of good leafy alfalfa hay. Hence the local price of hay and grain may be used to determine a fair price for sale or for trading. These data in conjunction with table 4 are often useful for farm inventory and other purposes.

COST

The cost of constructing a silo varies with the size, type, and price of materials and labor. In general a silo built of local materials, with farm labor, will cost the least. Table 5 gives a rough estimate of the cost of permanent upright silos.

TABLE 5.—*Approximate cost of permanent upright silos per ton of stored silage (roof and chute included)*[1]

Capacity	Cost	Capacity	Cost
Tons	*Dollars*	*Tons*	*Dollars*
25–50	7–12	100–150	4–8
50–100	5–9	150–200	4–7

[1] These figures, based on heights of from 2 to 3½ times the diameter, were compiled from actual costs to farmers, contractors' estimates, and manufacturers' and dealers' retail price lists for 1937.

HOW TO OBTAIN PLANS

Most of the extension services of the State agricultural colleges can furnish plans for the types of silos commonly used in their States or can indicate where information on special types of silos can be obtained. Many of the State agricultural colleges have bulletins on silos.

FOUNDATIONS

Foundations stand up well only on firm well-drained soil, and only if they extend below the frost line. In the North it is desirable that they extend 4 feet or more below the ground surface; in the South at least 2 feet. The width of the foundation base needed varies with the condition of the soil and the load to be supported. The foundation must be wider on loose soil than on firm soil. Recent investigations have shown that the walls carry from 30 to 60 percent of the total weight of silage depending on the roughness of the walls and the character of the silage. Tests by the Division of Agricultural Engineering in a 14- by 45-foot monolithic concrete silo showed that 60 percent of the weight of normal corn silage was supported by the walls.

Table 6 lists the expected foundation loads per foot of circumference of silo wall and the width of footings needed. The footing sizes are based on firm, dry soil with a load-bearing capacity of at least 2½ tons per square foot. If a tall silo is to be built, a reliable local builder should be consulted as to the bearing value of the subsoil and the proper width of footings to use. The foundation should be placed on uniform bearing, not part rock and part soil, and may be of concrete, brick, or stone. Where hard-burned brick are cheap, as is often the case near a brickyard, they can be used to advantage for a foundation. They should be laid in cement, not in lime mortar. If the foundation extends more than 1 foot above the surface of the ground it should be reinforced the same as the walls. Stone makes a good foundation, but in most areas concrete is stronger and generally cheaper than brick or stone.

TABLE 6.—*Loads on footings per foot of circumference of silos of different heights and the width of footings needed on soil of 2.5 tons per square foot bearing capacity*

Height of silo wall (feet)	Load and width of footings for silo walls of—							
	Concrete				5-inch tile		Wood (2-inch) or metal	
	6-inch monolithic		2-inch stave					
	Load per foot of circumference	Width of footings	Load per foot of circumference	Width of footings	Load per foot of circumference	Width of footings	Load per foot of circumference	Width of footings
	Tons	*Inches*	*Tons*	*Inches*	*Tons*	*Inches*	*Tons*	*Inches*
20	2.0	10	1.5	8	1.5	8	1.4	7
30	3.1	16	2.3	11	2.3	12	2.1	10
40	4.6	22	3.6	18	3.6	18	3.3	16
50	5.7	27	4.5	22	4.5	22	----------	----------

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The foundation for a round silo can be laid out as follows: Using a 2- by 4-inch scantling a little longer than one-half the diameter of the silo plus the width of the foundation walls, drive a fortypenny spike through one end of it and into the top of a stake set where the center of the silo bottom is to be. From the spike measure off on the scantling the distance to the outside of the foundation wall and nail on a marker with which to lay off the foundation line as shown in figure 1.

If the building site is not level, the marker should be lengthened (fig. 1) and moved up or down so the scantling can be held level as it

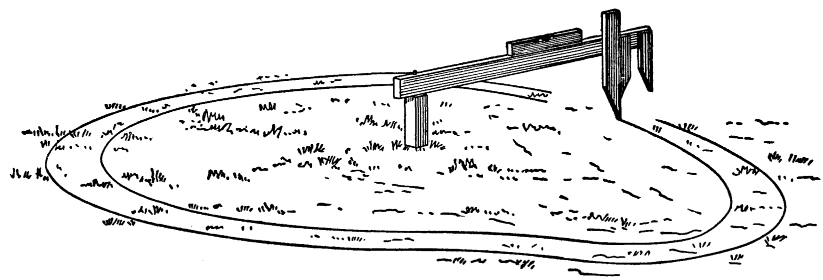

FIGURE 1.—Method of laying off the foundation for a silo.

is moved to mark out the foundation circle. On very uneven ground it may be difficult to make the line continuous, in which case points should be marked every few inches and joined afterward.

In firm soil the earth between the two lines can be excavated, leaving a trench the walls of which serve as forms for a concrete foundation. Otherwise the earth inside the outer circle must be

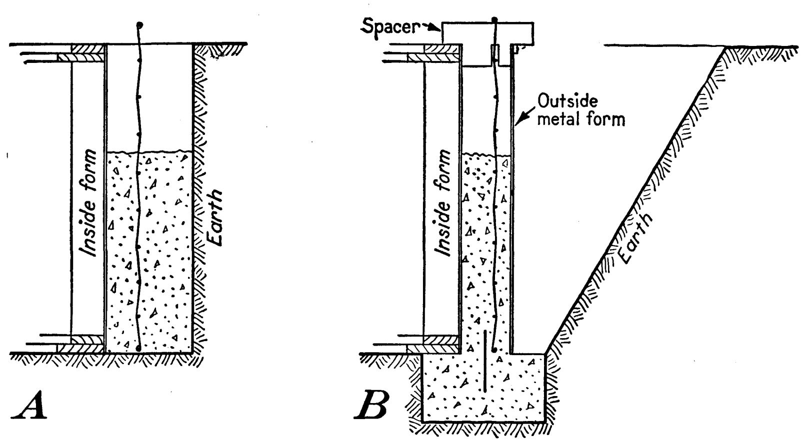

FIGURE 2.—*A*, Method of constructing foundations without footings for silos with pits in firm soils; *B*, method used for silos with pits when footings are required.

excavated to firm ground below the frost line. A plumb line should be used so that the walls can be dug true. Generally the earth is firm enough to stand without danger of caving, and, lined with tar paper, may serve as an outside form in building the foundation (fig. 2, *A*).

If the dirt caves in, the foundation should be built as shown in figure 2, *B*, in which case the pit must be dug large to give ample room for placing and removing the outside form. Many failures of masonry structures have been caused by poor and insufficient foundations. If there is no good location for a foundation and the silo is very large it is well to put in a special footing to distribute the weight over a larger area. (See fig. 2, *B*, and table 6, for footing loads and sizes.) Another way to get wider weight distribution is to build the foundation and floor in one piece.

If the silo is to be built without a pit, the marker is moved toward the center stake a distance equal to the width of the wall or footing and a second circle laid off.

Figure 3 illustrates how forms are built for a foundation wall extending above ground and how the anchors are placed for holding the walls. The anchors may be machine bolts, strap iron, eyebolts, or reinforcing iron, according to the type of silo planned. These are located in the foundation and spaced so as to be easily fastened and give firm anchorage to the wall. In masonry silos the wall reinforcing extends into the foundation or the footing. For stave and wood

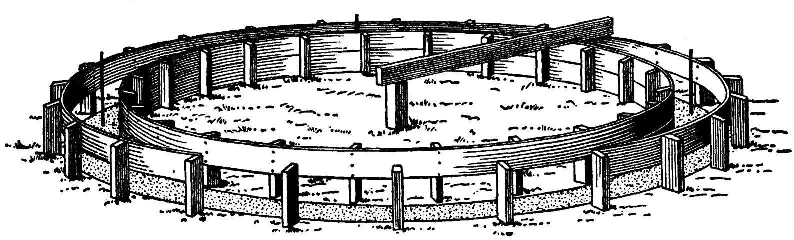

FIGURE 3.—Form for foundation extending above ground, partly boarded up.

silos the inside diameter of the foundation wall should be 4 inches less than the inside diameter of the silo, making a 2-inch shoulder between the inside of the silo wall and the inside of the foundation to allow for shrinkage movement of staves and for imperfections in the wall.

When concrete is used the following brief information is helpful:

Use a standard portland cement, keeping the sacks of cement in a dry place and off the ground. Obtain a good, clean, coarse sand and clean, coarse aggregate of gravel or broken stone graded in size from ½ to 1½ inches; mix these together with water free from acids or alkali. Water fit to drink is suitable for concrete; drainage water from the barnyard or muddy water should not be used. Mix the concrete to a jellylike consistency with the least water that will give easy delivery to forms without being sloppy. About 4 or 5 gallons of water to a sack of cement is ordinarily required, the quantity varying with the dryness of the aggregate. Except for very large silos a 1:2½:4 concrete is suitable for foundations.

Satisfactory concrete may be obtained either by hand or machine mixing, but machine mixing is recommended. Some mixtures commonly used for stucco plaster, footings, and walls are given in table 7, which is useful for estimating the quantity of material required. A sack of cement is approximately 1 cubic foot.

TABLE 7.—*Proportions and approximate quantities of materials required for making 1 cubic yard of concrete in place*

Proportion of the ingredients			Quantity of material[1]		
Cement	Sand	Gravel or stone	Cement	Sand (damp and loose)	Gravel (loose)
			Sacks	*Cubic yards*	*Cubic yard*
1	1.5		15.5	0.86	
1	2.0		12.8	.95	
1	3.0		9.6	1.07	
1	2.0	3.5	6.5	.48	0.84
1	2.5	4	5.6	.52	.83
1	2.5	5	5.0	.46	.92
1	3.0	5	4.6	.51	.85

[1] Quantities may vary as much as 10 percent, depending on the aggregate.

More complete information on mixing and placing concrete is given in Farmers' Bulletin 1772, Use of Concrete on the Farm, and in booklets obtainable from cement dealers.

FLOORS

If the earth in the bottom of the silo is firm, porous, and comparatively dry, no provision need be made for drainage, and a floor may be omitted; however, a concrete floor will make the silo easier to clean and will keep rats from burrowing underneath the foundation wall. If natural drainage is not good, a drain should be laid, open at the center of the concrete floor and sloping away from the wall to an outlet. Where grass or legume and molasses or other high moisture silage is made several drains through the foundation wall are often effective in removing excess juices. These drains generally are placed above ground and may be fitted with plugs, caps, or valves to prevent the entrance of air when drainage ceases (fig. 4).

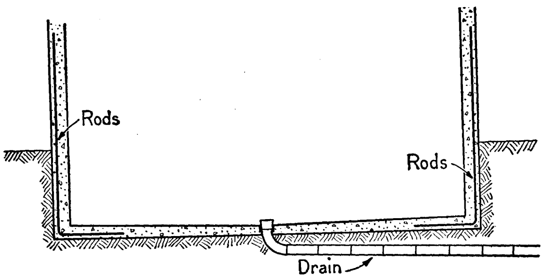

FIGURE 4.—Tile floor drain.

The floor should be at least 4 inches thick and may have a sealing joint of tar between it and the wall. In very soft soil the foundation load may be distributed over the entire floor by pouring the foundation and floor as a unit and using reinforcing bars 12 to 18 inches apart extending across the floor and into the foundation wall. (Table 8.)

REINFORCING

All silos must be reinforced to withstand the pressures exerted by the silage and by high winds. The amount of reinforcing needed depends on the dimensions of the silo and the crop stored. If a silo is used for other than corn silage, it is well to provide for the maximum probable load. Tests made by the Division of Agricultural Engineering gave an average horizontal pressure of 11 pounds per square foot per foot of depth of corn silage, which is too low for silage of sunflower, pea vine, hay and molasses, or very high-moisture corn. Tests indicate that it is advisable to use a unit pressure for hay and molasses silage approximately one and three-fourths times that for normal corn

silage, or about 19 pounds per square foot per foot of depth. Tables 8 and 9 are based on these pressures and give the sizes of horizontal reinforcing required for any type of silo. Wood or concrete stave silos are reinforced with hoops placed around the outside; in masonry silos, such as tile, brick, or concrete block, the reinforcing is of wire, round or square rods, or iron flats placed in the mortar joints between courses. Hoops must be properly spaced and tightened. To avoid stripping, each nut should be given enough turns to show several threads outside the nut. Hoops should have rolled threads so as not to reduce the cross-sectional area of the rod, and the next larger size of nut. They may be either plain or galvanized. Painting plain hoops prevents weakening by rust and unsightly stains on the walls.

TABLE 8.—*Number of pieces of No. 3 reinforcing*[1] *wire or ⅜-inch round bars required in masonry silos for horizontal reinforcing, spaced at 1-foot intervals*[2]

Distance below top (feet)	Pieces of reinforcing for silos of diameter indicated to store—											
	Corn silage						Hay and molasses silage					
	10 feet	12 feet	14 feet	16 feet	18 feet	20 feet	10 feet	12 feet	14 feet	16 feet	18 feet	20 feet
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Top	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	0	1	1	0	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	2
6	0	0	0	1	1	1	1	1	1	1	2	1
7	1	1	1	1	1	1	1	1	1	2	1	2
8	0	1	1	1	1	1	1	1	2	1	2	2
9	1	0	1	1	2	2	1	2	1	2	2	2
10	1	1	1	2	1	1	2	1	2	2	2	3
11	1	1	1	1	2	2	1	2	2	2	2	2
12	1	1	2	2	1	2	2	1	2	2	3	3
13	1	1	1	1	2	2	1	2	2	3	2	3
14	1	2	2	2	2	2	2	2	3	2	3	1
15	1	1	1	2	2	2	2	2	2	3	3	2
16	1	2	2	2	2	2	2	2	3	3	1	1
17	2	1	1	2	2	3	2	3	3	3	2	2
18	1	2	2	2	2	2	2	2	3	1	2	2
19	2	1	2	2	2	3	2	3	3	2	2	2
20	1	2	2	2	3	2	3	3	1	2	2	2
21	2	1	2	3	1	1	1	1	2	2	2	2
22	1	2	2	2	2	2	2	2	1	2	2	3
23	2	2	2	3	1	1	1	1	2	2	2	2
24	2	2	2	2	2	2	2	2	1	2	3	3
25	2	2	2	3	1	1	1	2	2	2	2	2
26	2	2	3	1	2	2	2	2	2	2	3	3
27	2	2	2	2	1	1	1	2	2	2	2	3
28	2	2	3	1	2	2	2	2	2	3	3	3
29	2	3	2	2	1	2	1	2	2	2	2	3
30	2	2	3	1	2	2	2	2	2	3	3	3
31	3	3	1	2	2	2	1	2	3	2	3	3
32	2	2	2	1	2	2	2	2	2	3	3	3
33	3	3	1	2	2	2	2	2	3	3	3	4
34	2	3	2	1	2	2	2	2	2	3	3	3
35	3	3	1	2	2	2	2	2	3	3	3	4
36	------	3	2	2	2	2	------	3	2	3	4	3
37	------	3	1	2	2	2	------	2	3	3	3	4
38	------	3	2	2	2	3	------	3	2	3	4	4
39	------	3	1	2	2	2	------	2	3	3	3	4
40	------	3	2	2	2	3	------	3	3	3	4	4
41	------	------	2	2	2	2	------	------	3	4	4	4
42	------	------	2	2	2	3	------	------	3	3	4	4
43	------	------	2	2	3	2	------	------	3	4	4	5
44	------	------	2	2	2	3	------	------	3	3	4	4
45	------	------	2	2	3	3	------	------	3	4	4	5
46	------	------	------	2	2	3	------	------	------	4	4	4
47	------	------	------	3	3	3	------	------	------	4	4	5
48	------	------	------	2	2	3	------	------	------	4	5	5
49	------	------	------	3	3	3	------	------	------	4	4	5
50	------	------	------	2	2	3	------	------	------	4	5	5

1 The cross-sectional areas of the different sizes of reinforcing wire and bars are: No. 3, 0.0467 square inch; ⅜-inch rods 0.1105 square inch. All figures below the horizontal line represent pieces of ⅜-inch round bars.

2 This amount of reinforcing steel is based on a safe working stress of 18,000 pounds per square inch and can be spaced 4, 8, 12, 15, 24, or 30 inches, according to the type of material and the size of the units used.

TABLE 9.—*Spacing of 9/16-inch hoops*[1] *for stave silos*

Distance of hoop below top (feet)	Corn silage (diameter in feet)						Hay and molasses silage (diameter in feet)					
	10	12	14	16	18	20	10	12	14	16	18	20
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
0–2½	30	30	30	30	30	30	30	30	30	30	30	30
2½–5	30	30	30	30	30	30	30	30	30	30	30	30
5–7½	30	30	30	30	30	30	30	30	30	30	30	30
7½–10	30	30	30	30	30	30	30	30	30	30	30	30
10–12½	30	30	30	30	30	30	30	30	30	15	15	15
12½–15	30	30	30	30	30	30	30	30	15	15	15	15
15–17½	30	30	30	30	30	15	30	15	15	15	15	15
17½–20	30	30	30	30	15	15	15	15	15	15	15	10
20–22½	30	30	30	15	15	15	15	15	15	15	10	10
22½–25	30	30	15	15	15	15	15	15	15	10	10	10
25–27½	30	30	15	15	15	15	15	15	15	10	10	10
27½–30	30	15	15	15	15	15	15	15	10	10	10	7½
30–32½	30	15	15	15	15	15	15	10	10	10	7½	7½
32½–35	15	15	15	15	15	10	15	10	10	10	7½	7½
35–37½	------	15	15	15	10	10	------	10	10	7½	7½	7½
37½–40	------	15	15	15	10	10	------	10	10	7½	7½	5
40–42½	------	------	15	10	10	10	------	------	7½	7½	7½	5
42½–45	------	------	15	10	10	10	------	------	7½	7½	5	5
45–47½	------	------	------	10	10	10	------	------	------	5	5	5
47½–50	------	------	------	10	10	10	------	------	------	5	5	5

[1] Based on 18,000 pounds per square inch safe stress. All hoops to have rolled threads and nuts of the next larger size.

In a monolithic concrete silo the material used for reinforcement may be steel rods, bars, or wire mesh, provided the amount used is sufficient to withstand the pressure. The material most convenient and readily obtained at a reasonable cost is the common woven or welded steel-mesh reinforcing cloth, 32 or 36 inches wide, with horizontal wires ranging from No. 9 to No. 3 or larger. The horizontal strength per square foot of this reinforcing should correspond to sizes given in table 8. This wire is readily placed in position and is not easily displaced while the form is being filled. Reinforcing wire should be free from sharp kinks or bends, and to be most effective should be placed within 1 or 2 inches of the outer wall (fig. 2, *B*). Old or damaged wire of unknown strength should never be used.

The length of wire-mesh strip for a given diameter of silo is given in table 10, which is based on reinforcing having No. 3 wires for horizontal stands. This allows about 12 inches for lapping and securely fastening the ends by binding with No. 16 soft-iron wire to prevent slipping. Each strip of wire should also be fastened to the strip below by the same means. If 3/8-inch bars are used they should lap 18 inches and be held in place by being attached to 3/8-inch vertical rods spaced 24 inches on centers.

TABLE 10.—*Length of wire-mesh sections for reinforcing concrete wall*

Diameter of silo (feet)	Length of strips required to make circumference[1]		Diameter of silo (feet)	Length of strips required to make circumference[1]		Diameter of silo (feet)	Length of strips required to make circumference[1]	
	Feet	*Inches*		*Feet*	*Inches*		*Feet*	*Inches*
10	34	9	13	44	2	16	53	7
11	37	11	14	47	4	17	56	9
12	41	1	15	50	6	18	60	0

[1] Includes 12 inches for lap and fastening.

DOORS AND DOORWAYS

Silo doors must close tightly to prevent air leakage and must be flush with the inner wall to avoid formation of air pockets as silage settles. Frames must be strong to resist silage pressure.

Two kinds of door openings are in general use—intermittent and continuous. A common size for doors is 20 inches wide by 30 inches high. The vertical space between the intermittent doorways is from 2½ to 3 feet.

The continuous doorway is convenient for the removal of silage, but particular care is necessary in framing it to obtain the desired strength. Special features of door construction particularly adapted to different types of silos are described later. Doors may be fitted with hooks or hinges so they can be closed or replaced as the silo is emptied, a procedure that reduces draft through the silo and makes working conditions more comfortable and prevents loss or misplacing of doors.

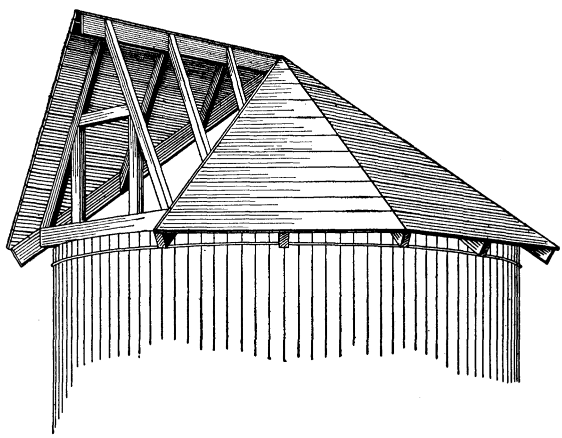

FIGURE 5.—Roof with space for glazed window in gable.

CHUTES

A chute is desirable on all silos to prevent the scattering of silage. In building the doorframe provision should be made for the attachment of the chute. If the chute is not too large, climbing the silo will be more convenient and safer. If a continuous doorway is used, the reinforcing rods across it will serve as a ladder; otherwise a ladder must be attached to the chute. Bolt holes for the attachment of the chute may be left in a concrete wall by placing square, tapered wood pins or pieces of cornstalks in the wall as the forms are being filled. These pins should be greased so they may be easily punched out. The form of chute and the material used will vary with the type of silo, as may be seen by referring to figures 20, 23, and 31.

ROOFS

A roof is not essential, but it is desirable for several reasons: It adds to the stability, appearance, and life of the silo, retards freezing, reduces spoilage by keeping rain and snow out, discourages pigeons and sparrows from feeding on the silage, and makes the work of removing silage more agreeable. A simple trap door in the room to admit the silage carrier or blower pipe is sufficient, but a glazed dormer window in a roof framed as illustrated in figure 5 admits light and makes the use of artificial light less necessary. When electricity is available lights with reflectors in the top of the chute and roof are a great convenience and should be provided when the silo is constructed. The filling door should be easily accessible from the ladder or chute.

When the door is across the silo from the chute a catwalk is a necessity for safety in placing or removing the blower pipe.

Gambrel, dome, and half-pitch roofs are most economical of space and provide more headroom for maximum filling (fig. 6). In some cases the roofs may be made of galvanized metal with movable sections which open and allow filling to the top. The form of anchorage for the roof plate will vary with the type of construction; with stave silos, strap bolts passing through the plate and bolted to the tops of the staves are used; with masonry silos, anchor bolts may be set in concrete (fig. 7), or in top courses of tile or brick. On masonry silos a strong and durable roof may be made of a thin shell of concrete poured in a conical form.

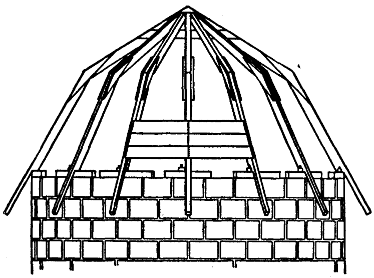

FIGURE 6.—Framing for a gambrel roof.

LIGHTNING PROTECTION

The silo, usually the tallest building in the farmstead group, forms a natural target for lightning. Destruction of wood silos or serious damage to those of masonry may be greatly reduced by installing lightning rods. (See Farmers' Bulletin 1512, Protection of Buildings and Farm Property from Lightning.) The air terminal should be securely fastened to the peak of the roof and the cable extending to the ground firmly attached by a strong fastener to the silo roof and walls. The electrical connection may be completed by extending the down conductor to a ground 8 or 10 feet deep reaching soil permanently moist.

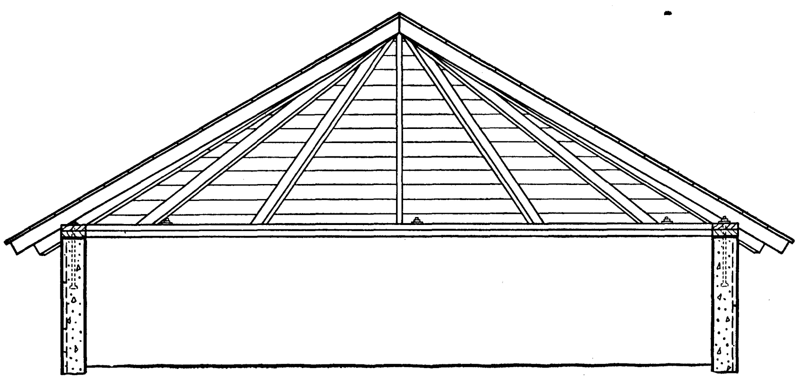

FIGURE 7.—Pitch-roof construction showing anchorage of plate to a masonry wall.

Place the down conductor where it will not be easily damaged by wagons or trucks and protect from injury if necessary. If the nearby barn is rodded, cross-connect to the nearest down conductor on the end of the barn.

SCAFFOLDING

Safety is of first importance in the erection of scaffolding. In building high silos it is particularly important that the scaffold uprights be plumb and firmly braced. It is a good practice to set them in the ground 4 to 6 inches. Uprights of 2- by 4-inch scantling doubled and

overlapping at the joints are convenient. However, long straight poles can often be obtained on the farm at lower cost. The number of uprights needed will vary from 7 for a small silo to 17 or more for a larger one when inside scaffolding is used (figs. 8 and 10). The uprights are usually braced to a center pole.

In the erection of most silos inside scaffolding is used, but wood-stave silos require an outside scaffold. Such outside scaffolding is made up of pairs of upright posts connected with horizontal bars spaced at intervals required for the working platform. From 8 to 18 or more pairs are needed, the inner posts placed about $1\frac{1}{2}$ feet from the silo wall so as to leave a clear working space, connecting the pairs with horizontal and diagonal braces, as shown in figure 9.

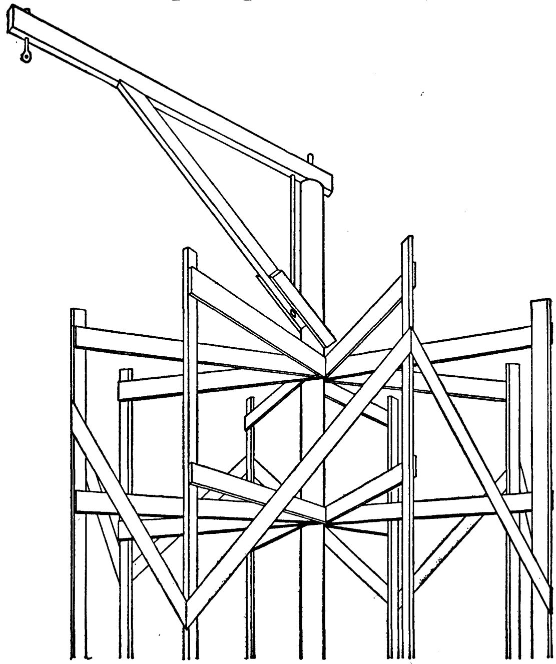

FIGURE 8.—Top portion of inside scaffolding showing rotating device for hoisting concrete.

WALL TREATMENTS FOR NEW AND OLD SILOS

Any painting or treating of the walls of a new silo deemed desirable is best done before the scaffolding is removed. The interior surface of walls should be smooth. Any coating applied should have a smooth, lasting finish, be impervious to silage acids, and stop air and water leakage. Some of the common coatings effective for a few seasons are plaster or cement wash for masonry walls and asphalt or commercial bitulithic paints for all kinds. Creosoted wood staves need no further treatment for several years. Silage acids have no effect on hard glazed tile, and for this reason some manufacturers make special silo tile that fit closely on the inside, leaving very little mortar exposed. Well-made concrete is highly resistant to these acids, but careless mixing and poor workmanship may result in rapid deterioration. Special treatment of the interior surface of a silo will not adequately protect poor-quality concrete. It is much more effective to use high-quality concrete in the silo wall itself in the first place. A wash of cement and water of the consistency of thick paint may be applied to the wetted concrete wall to cover irregularities. Among the best known coatings to prevent action of silage acids are linseed oil and asphalt or coal tar thinned with gasoline. This coating may be renewed from year to year as required. When asphalt or tar is applied, the usual gasoline precautions should be observed.

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A cement wash may be made with portland cement and iron filings. This mixture requires $4\frac{1}{2}$ pounds of water, 10 pounds of cement, and $2\frac{1}{2}$ pounds of No. 126 iron filings for a batch that will cover 110 square feet. The mixture must be stirred frequently to keep the filings from settling out. Iron filings can be obtained either with or without sal ammoniac. Sal ammoniac hastens the rusting of the filings.

Because galvanized metal is readily attacked by silage acids, new silos of this material are painted inside with refined coal tar thinned

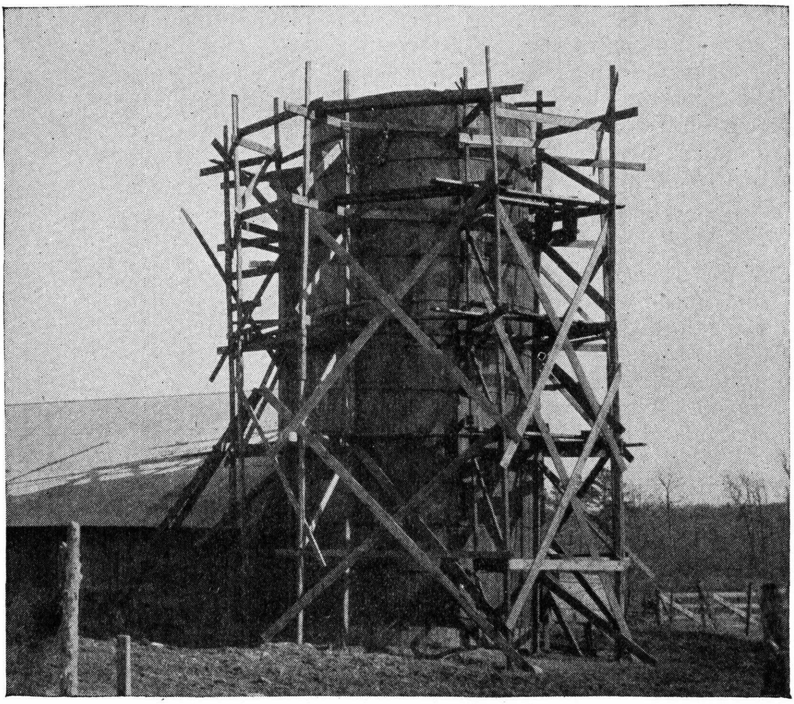

FIGURE 9.—Outside scaffolding for erecting a wood silo.

with gasoline or linseed oil. Commercial preparations are also available for this purpose. Aluminum-flake paint may be used on the exterior to improve the appearance.

The life of a silo can be extended by proper upkeep and repair. Some farmers paint their silos each year after the silage is fed out, using a low-cost preparation. Others apply more lasting coatings once in 2 to 5 years.

Old masonry silos having poor mortar joints can be reconditioned by cleaning the walls, pointing joints and cracks with rich cement mortar, and then painting them with a tar or asphaltic preparation. This is highly important with block or brick walls, where the reinforcing is between courses, for once the reinforcing has rusted out it cannot be replaced without tearing down the silo. Where the walls leak, a coat of rich cement plaster might well be added.

Concrete staves should be similarly protected against injury from silage juice. Since they are generally $2\frac{1}{2}$ to 3 inches thick there is

not much safety margin for reduction in strength of the walls. If the staves become much thinner they may fail when the silo is full. Well-made monolithic concrete walls need little attention except painting. If the concrete was of poor quality and the silage acids have made it very rough, it may be necessary to scrape and wash the walls thoroughly, and, after soaking them with water, add a coat of rich cement plaster.

It is possible to replace rotted parts of the walls of wood silos, but the better way is to keep the walls painted. Lead paints contaminate silage with poisonous lead and should never be used. Creosoting is probably the most favored treatment for wood walls. Various commercial preparations are also used.

A metal silo should be kept painted from the time it is put up since little can be done once the metal has rusted. Patches may be bolted or riveted over small damaged areas, but it is not likely that a silo so damaged will remain serviceable long. Where corrosion has just started, it can usually be stopped by thorough cleaning and painting. If the silo is leaking where the sheets of metal come together the old bolts can be replaced, a few at a time, and the joints filled with mastic before the bolts are drawn tight.

MONOLITHIC CONCRETE SILOS

Masonry silos—concrete, tile, and brick—are cylindrical. Those of concrete may be of stave, block, or monolithic construction. Tile and brick silos differ mostly in size and shape of units. Because of their weight freight can be a large factor in the cost. However, these materials are manufactured in many sections of the country.

The word "monolithic" means in this case a solid or one-piece wall of concrete. With careful workmanship and a trained crew, a satisfactory silo of medium height can be built with a 4-inch wall, but the ordinary builder will find 6-inch walls easier to build. The same thickness should be continued to the top because of the difficulty of adjusting the forms for a wall decreasing in thickness toward the top.

FORMS

Inner and outer circular forms are needed which can be set up with a 6-inch space between them. Sometimes forms may be rented from the State agricultural college or from a lumberyard, or cost may be cut by cooperating with a neighbor in building them or by buying used forms.

The forms are commonly built 3 feet high, and approximately 33 inches of wall can be built with each setting. They are so constructed that after each course of 33 inches has been placed they can be loosened and raised for another course (fig. 10). In resetting, the forms are allowed to lap about 3 inches over the wall just placed, which helps greatly in getting them into proper position and keeping the walls plumb.

Forms may be of sheet metal or wood, but metal is much better, since the forms are lighter than those of wood and they make a smoother wall. Twenty-two-gage black or galvanized sheet iron 36 inches wide may be used. If, however, the diameter of the silo is to

be 16 feet or more, sheets 30 inches wide might better be used, because in such cases one course around the silo at the reduced height of wall would make a day's work. Galvanized-iron forms last longer than

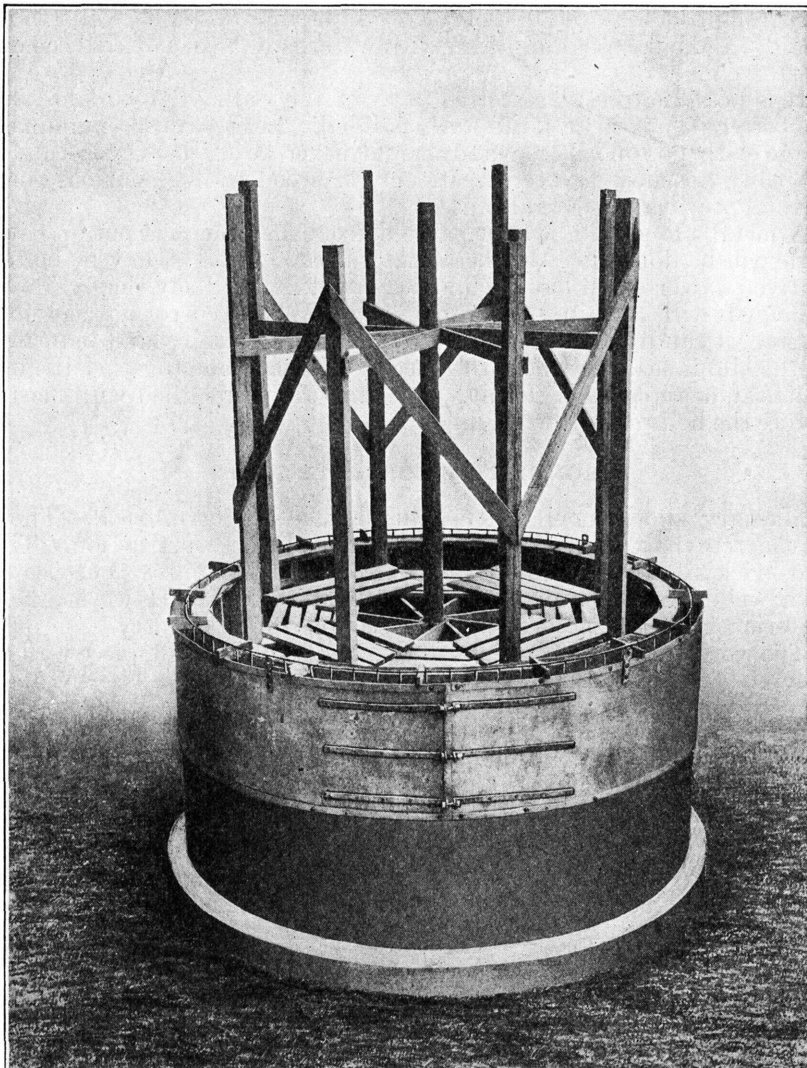

FIGURE 10.—Silo form in position showing the lower part of the wall and scaffold. Note how the scaffold is cross braced.

black-iron forms and, if properly cared for, can be used several seasons for a number of silos of the same diameter.

For the inside form it is necessary to build two supporting circles (figs. 10, 11, and 12) to which the sheet iron or wood, as the case may be, is nailed. These circles are built of 1- by 6-inch material, rough or dressed, of a length depending upon the diameter of the silo, so that 16

pieces will exactly make the circumference. It is not an easy matter to compute the lengths of chords for the various diameters, so they are given below. In figure 11 the chord is the distance from *a* to *b*.

TABLE OF CHORDS

Diameter of silo (feet):	Chord measurement Feet	Chord measurement Inches	Diameter of silo (feet):	Chord measurement Feet	Chord measurement Inches
10	1	11⅜	15	2	11
11	2	1¾	16	3	1½
12	2	4	17	3	3¾
13	2	6⅜	18	3	6⅛
14	2	8¾	20	3	10¾

LAYING OUT TEMPLETS FOR INSIDE FORMS

Figure 11 shows how to lay out the pieces to be used as templets, or patterns, by which to cut the pieces which, when laid end to end, are to form the supporting circles for the inside form when sheet iron is used. For this part of the work the barn floor or any other large clear space is handy. If no better place is available, a concrete mixing board can be used.

Select a straight piece of 1- by 3-inch board about a foot longer than half the diameter of the proposed silo, and with a tenpenny nail tack one end to the floor so that the slat will be free to swing about. From this nail, representing the center of the silo, measure on the slat one-half the length of the inside diameter. Here drive a nail until the point extends through far enough to scratch a clear mark on the floor as the slat is swung around on the center *o*, as shown in figure 11. This circle represents the inside face of the wall. An arc equal to one-quarter of the circumference is sufficient. From any point which has been determined to be *a* on the arc, measure the length of the chord in figure 11 as given in the table of chords for the diameter of the proposed silo, and find point *b*. With a straightedge laid through the points *a* and *o*, and also through *b* and *o*, draw short lines on the floor a few inches toward the center from *a* and *b*, respectively. On these lines measure inward 4 inches from points *a* and *b*, and locate points *c* and *d*.

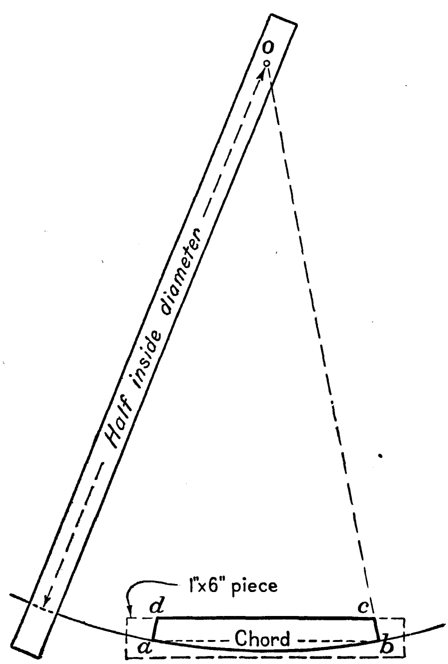

FIGURE 11.—Method of laying out templet.

Next take a piece of the 1- by 6-inch board and lay it on the arc with the inside edge flush with points *c* and *d*, as shown in figure 11.

With several small nails tack it to the floor; then lay off the arc again on this piece, and with the straightedge re-mark lines *ad* and *bc*. The piece is now ready to be taken up and sawed. The resulting pattern, or templet, will serve to mark out the 64 pieces necessary to build the two inside circles.

The curved pieces can be sawed by hand, but it is better and cheaper to have the work done at a mill or shop equipped with a band saw.

BUILDING THE CIRCLES

Each of the supporting circles is built two-ply; that is, the pieces are lapped so as to break joints and placed on the circle so that they

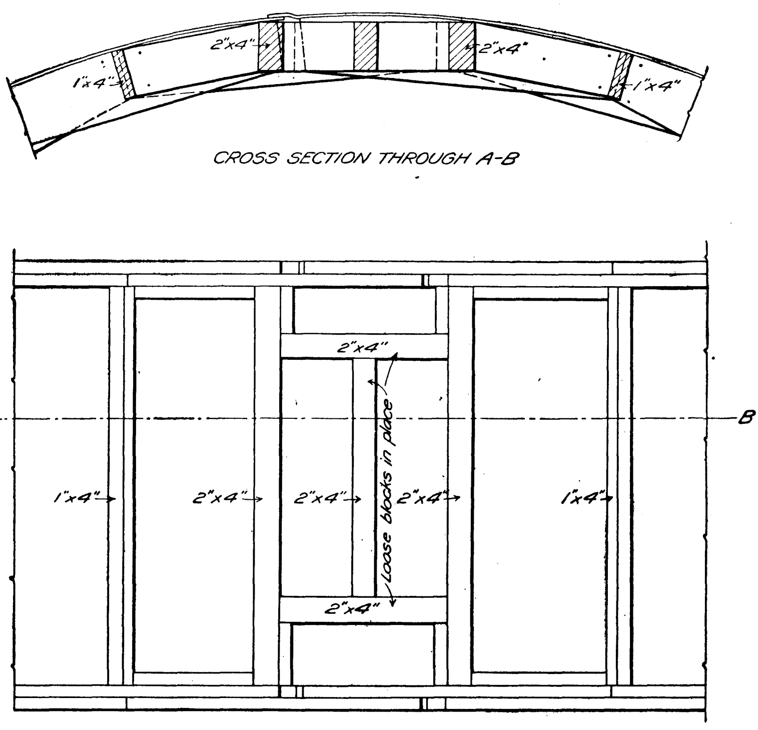

FIGURE 12.—Part of inside form, showing the method of fitting the form to the wall and holding it in place.

will fit the curve. Before starting to nail the pieces together, mark out the whole circumference on the floor or on level ground with the slat, as shown in figure 11, and build the circles accurately by laying the pieces flush with the mark. It is important that the circles be well nailed with eightpenny nails driven through and clinched. While the circles are being built, approximate points of division into quarter circles can be marked and those pieces nailed sparingly until after the circle is completed. It is generally safer to build the circles complete and then divide into quarter sections rather than to build

each quarter separately; this division into parts is for convenience in loosening and resetting the forms.

Remove the nails in one-half of every fourth piece in the top layer of each circle. This divides each circle into four equal parts, with lapped joints.

BUILDING THE INSIDE FORM

Three inches should be cut from each end of each quarter section of the circles supporting the forms to allow the sections to slide together when they are to be removed from the wall. Next, temporarily nail the quarter sections together at points of division and brace the top circle directly over and 32 inches above the lower one. See that both circles are perfectly level and that the joints in the upper circle are directly above the joints in the lower circle, and then proceed to nail in securely, between the top and bottom circles, 1- by 4-inch studding, 32 inches long, placing the studs carefully plumbed from 12 to 18 inches apart, as shown in figure 12, to keep the iron from bulging. The end studs in each quarter section should be of 2- by 4-inch material, supported by 1- by 4-inch blocks cut in between the 2- by 4-inch stud and the next 1- by 4-inch stud, and nailed to the circles. Blocks 1 by 4 inches should then be nailed vertically on the opposite side of the 2- by 4-inch studs to hold in place the loose blocks that are used in fitting or releasing the forms from the wall (fig. 12).

Nail the sheet iron on with sixpenny nails, and nail securely, but before beginning to nail the iron on see that it is cut to the proper length. The sheet for each quarter section should be just 3 inches longer than one-quarter of the circumference. If several sheets are required to make a single quarter section, they should be carefully riveted together with a double row of flat-headed rivets. Since the quarter sections lap 3 inches, and in removing need to slide together several inches farther, it is necessary to leave one end of the sheets loose 8 to 10 inches from the end, while the other end should be nailed all the way.

BUILDING THE OUTSIDE FORM

The outside form is made up of four sections of 22-gage black or galvanized iron, each section being 3 inches longer than one-quarter of the outside circumference of the wall, to provide for the lap. The upper edge of each section is reinforced on the outside with a $\frac{3}{16}$- by $1\frac{1}{4}$-inch strap iron securely riveted to the sheet and cut back about 3 inches from each end of the sheet to allow for lapping.

LUGS AND BOLTS FOR OUTSIDE FORM

The quarter sections are joined and drawn together by means of bolts and lugs, the latter made from $\frac{3}{8}$-inch tire steel and riveted on the forms, as shown in figure 13; three pairs of lugs bent to the outside circumference of the wall are used at each joint, the lowest pair being placed 2 inches from the lower edge of the form, the upper pair 4 inches from the upper edge of the form, and the third pair halfway between. Note that in one end of the section the lugs are riveted in flush with the edge of the iron, while at the other end they are set in 4 or 5 inches from the edge, to permit a lap. The lugs should be made about 32 inches

long, bent up 2 inches at one end, with a ½-inch hole drilled in the bent-up end. The lugs are securely riveted to the sheets with five flatheaded

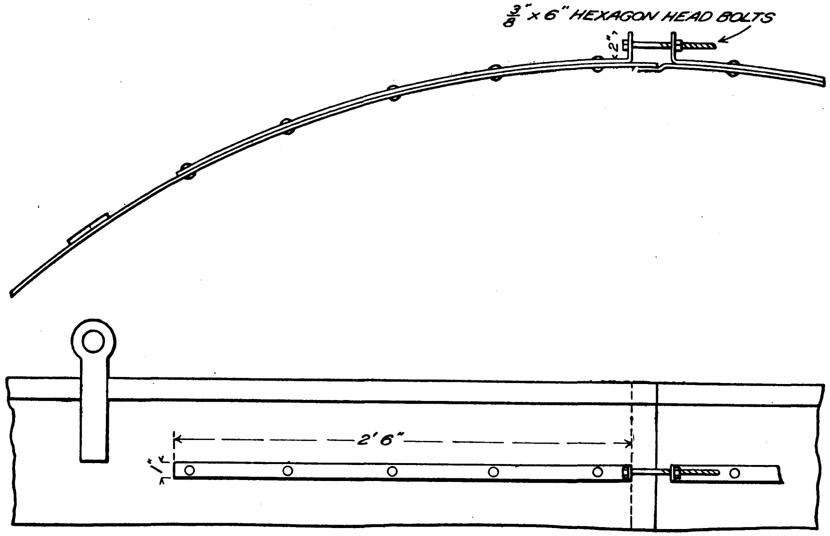

FIGURE 13.—Method of joining sections of outside forms.

rivets in each strap. For drawing the sections together use ⅜-inch bolts 6 inches long with hexagonal or square heads and nuts and extra-long thread (fig. 13).

Two wrought-steel eyes should be riveted to the upper edge of each section to facilitate the raising of the form.

SETTING THE FORMS

In building the wall the inside form is used from the footing up. Generally for the first 3 feet of wall the outside form is not needed, the earth wall of the pit serving as the outside form. As soon as the wall reaches the top of the ground the outside form must be placed in position. It should be so placed that one of its joints will come on the center line of the door opening. To space the outside form exactly 6 inches from the inner it is good practice to place 6-inch blocks at intervals along the bottom to hold the form temporarily in place. As the concrete is filled in, the blocks must be removed. For spacing the forms at the top a number of pieces of the shape shown in figure 14 will be found useful.

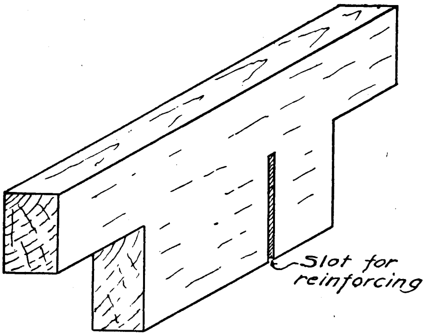

FIGURE 14.—Spacing block.

The greatest care must be taken to have both forms started level across the top and the sides plumb. If on one side of the silo the

forms are higher than on the other they are out of round, and consequently the wall at some places will be thicker than at others, thus making it impossible to build the wall plumb. The diligent use of a plumb bob and a good level at each raising will save much annoyance later.

FILLING THE FORMS

The strength, quality, and life of a monolithic concrete wall depend largely on the care used in proportioning, mixing, and placing the concrete. Care must also be taken to have the correct amount of reinforcing placed, as discussed on page 12. Figure 15 shows how carelessness in these matters will cause rapid deterioration in a silo.

Only a few inches in depth of concrete should be deposited at one place at a time; otherwise the forms may be forced out of plumb. As the concrete of a mixture of 1:2:3½ is put into the form it should be

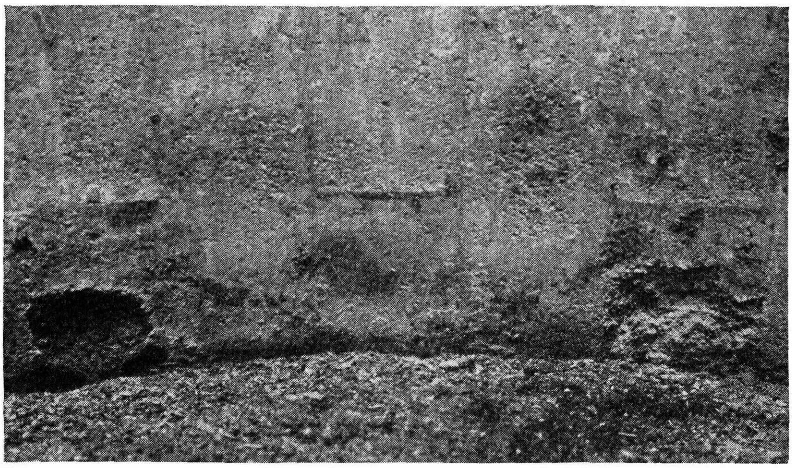

FIGURE 15.—The inside of a concrete silo, showing deterioration of the wall.

spaded with a piece of 1- by 3-inch board, sharpened to a bevel, to remove air bubbles and to avoid the formation of cavities. However, the spading must not be overdone, or the heavier aggregate will sink to the bottom, and the cement and water will rise to the top. Only enough water should be used to make a mixture that may be readily worked.

Coal scuttles are satisfactory for carrying and pouring the concrete and, if care is taken not to overload them, three will last for the whole job. A rope and single pulley may be used for elevating the scuttles.

The exterior surface of the silo can be kept smooth by greasing the outside form at each raising with soap, cheap oil, graphite, or grease. No grease should be used on the inside form, as the inside surface is to receive a brush coat of pure cement wash. Small particles of cement will adhere to this form each time it is raised, and before it is used again they should be removed with a wetted broom or a wooden trowel. If they are not removed, an undue quantity of concrete adheres, making the wall unnecessarily rough.

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As the forms are raised the fresh wall is exposed to the air and sun, and there is danger, particularly in summer, of the outside surface drying and curing more rapidly than the inside, thus causing cracks. To prevent this, the outside wall should be soaked with water several times a day for a few days. When possible, it should be protected with canvas or burlap hung from the bottom of the outer form and kept wet.

At the end of the day the top of the concrete is not smoothed, but is left as rough as possible. A good plan is to roughen the top surface just as the concrete begins to set. The next day, before fresh concrete is added, the top surface is soaked with water and then sprinkled with dry cement, which helps make a good bond between courses.

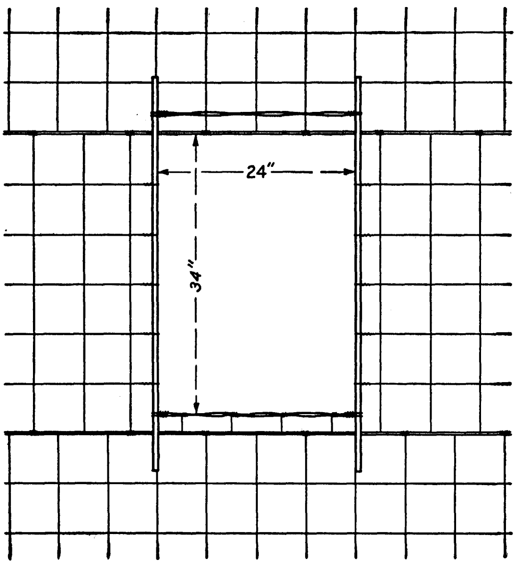

FIGURE 16.—Position of reinforcing around door opening.

At the end of each day's work the mixing board or mixer and all tools should be cleaned; otherwise the next day's work will be more difficult.

RAISING THE FORMS

Before loosening the forms for raising, a straightedge should be laid across their tops and leveled, and marks made on the uprights of the scaffold to show the position of the next set of supporting brackets for the inner form, which will be just 3 inches below the top of the forms. If this is done carefully there will be little trouble in resetting.

Small ropes are attached to the hoisting eyes in the top of the outside form; the bolts in the lugs at the joint of the form which is on the center of the door openings are now loosened sufficiently to permit the release of the form from the wall. By means of the hoisting ropes the form is raised to its new position and clamped temporarily to the wall by means of the lower lugs, or held suspended by the hoisting ropes attached to brackets from the scaffold. The reinforcement is set for the next course and laced to the reinforcement of the preceding course. Next, the loose key blocks of the inside form are removed and the form lifted by sections and placed temporarily on top of the wall. The supporting brackets are nailed in place and the working platform relaid. This done, the sections of the inside form are set in place on the brackets and the form clamped against the wall by replacing the loose blocks; the blocks should be marked for identification or fastened to the form so they will not be lost or interchanged.

Both sets of forms should now be plumbed and leveled, the outside form clamped in place, and spacing blocks inserted between the forms in sufficient numbers to hold the outside form to a true circle.

Care should be taken to avoid jarring the wall by heavy pounding, which is likely to injure the green concrete in the process of setting. The forms should not be removed until the concrete has set sufficiently. A good working plan is to raise and fill the forms in the morning and then leave them undisturbed until the next morning.

DOORS AND DOORWAYS

Special care must be taken to have the reinforcing around the doors as strong as in any other part of the wall. Figure 16 shows how a ⅝-inch rod, or its equivalent, should be placed on each side of the opening about 2 inches from the door form. The horizontal strands of the reinforcing are cut to admit the door form, and the ends are securely wound around the iron rods; the rods should extend 6 or 8 inches above and below the door openings and should be tied together with several strands of No. 8 or No. 9 wire.

On account of the greater ease with which the silage can be removed, many prefer a continuous door opening. A continuous doorway can be made by setting 1-inch pipes vertically spaced at such a distance as to allow 4 inches of concrete between the pipe and the edge of the door opening. These pipes should extend about 1 foot into the foundation. The reinforcing wire is fastened securely to them, and ⅞-inch rods extending horizontally across the doorway are hooked around the pipes every 20 inches. These rods serve the purpose of preventing the doorjambs from spreading and carry the strain of the reinforcement across the door opening (fig. 17). They also form the rungs of a ladder for the silo.

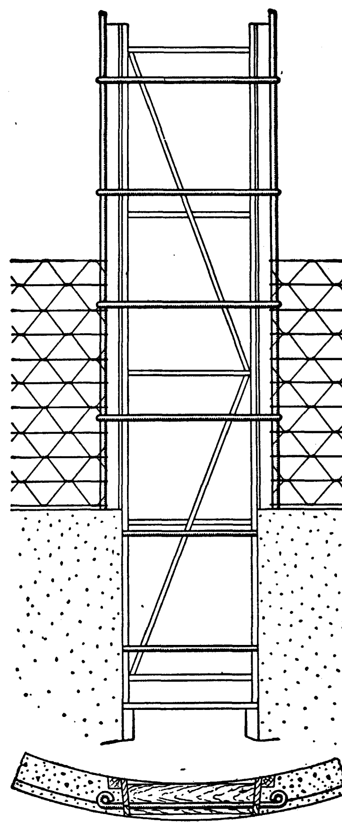

FIGURE 17.—Details of forming and reinforcing a continuous doorway.

The door itself may consist of 2-inch select planking 10 or 12 inches wide, cut in 2-foot lengths, or a door may be made by nailing together two thicknesses of 1-inch boards with building paper between them (fig. 18, *b*). These planks or doors fit into a rabbet on the inside edge of the doorway. This rabbet is formed in the concrete by the use of a form to which are attached 2- by 2-inch strips, as shown in figure 17.

After the reinforcement around the door opening has been arranged, as shown in figure 16, a form for the making of the door opening should be set in between the wall forms. This form is built of such size and shape (fig. 18) that when the concrete is molded about it a

2-inch rabbet is formed around the inside of the opening into which a wooden door can be set, this door being held in place by the pressure of the silage on the inside. The piece (fig. 18) which forms the rabbet at the bottom of the door opening should be left loose so that the concrete can be filled to the bottom of the door opening. In order that the form may be easily removed without injury to the wall, the top and sides are built with a slight taper, which permits the form to slip inward when lightly tapped on the outside. The bottom pieces

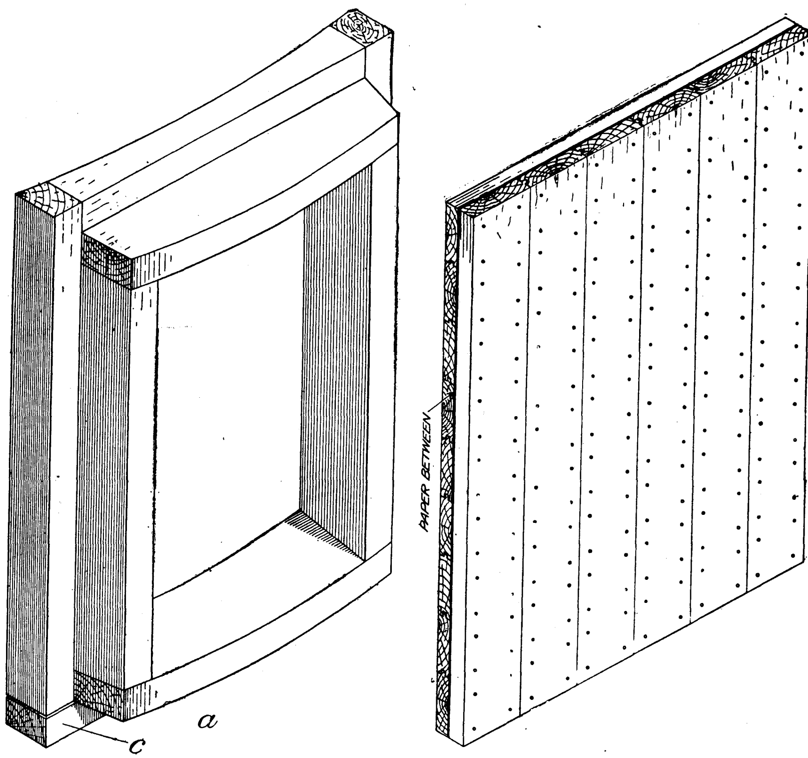

FIGURE 18.—Silo door and form for intermittent door openings.

or sill of the form should be left flat. All the surfaces should be dressed with a plane and greased before using. In placing the concrete about the form, considerable care must be taken to have it well worked in under the sill, or a rough job will be the result. The sills of the doors, especially of the bottom door, receive much wear, and should be protected by a piece of angle or strap iron, which is inserted at the time the rabbet piece is placed.

Unless it happens that the position of the doors exactly coincides with the alternate raising of the wall forms, two forms will be required. The top and bottom pieces of the forms are curved to the circumference of the silo and should be marked off with the slat shown in figure 6 in the same manner as the templet.

CONCRETE-STAVE SILOS

Concrete staves for silo walls are available in many parts of the country. They are generally 10 inches wide, 30 inches long, and 2½ inches thick. They are bound together with hoops, the joints sealed with cement plaster and the surface finished as noted on page 15. The size and spacing of the hoops are given in table 9. In the purchase of staves for such a silo (fig. 19) a guarantee should be obtained from the manufacturer that they will meet the requirements of the

FIGURE 19. Concrete-stave silo.

American Concrete Institute. In a silo higher than provided for in the tables in this bulletin it may be necessary to use thicker staves to give adequate safety against crushing. If a silo of unusual height is contemplated, a competent engineer should be employed to design the walls and foundation to take care of the excessive wall loads due to silage and wind pressure. Many manufacturers of concrete staves quote prices on a silo set up on the farm, and often this is the most economical way to buy.

Precast concrete doorframes are generally most satisfactory for this type of silo. The chute usually requires seven or eight staves from silo wall to silo wall, is supported on an iron bracket, and is bound to the silo with supplementary hoops, as shown in figure 20.

CONCRETE-BLOCK SILOS

Under some conditions concrete blocks are most economical and make a lasting and desirable silo (fig. 21). There are several different kinds of concrete blocks in use, such as straight or curved solid blocks, with or without reinforcing, two-piece blocks, and straight or curved blocks with air spaces and with the top bed grooved to receive the

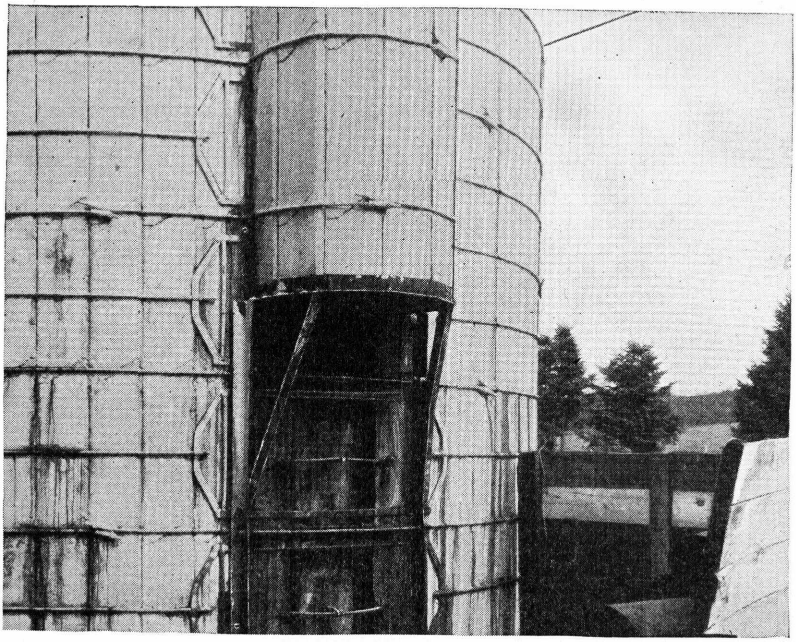

FIGURE 20.—Method of supporting a stave chute. Note how the intermediate hoops are carried across the doorway by iron straps spread to give unobstructed openings.

reinforcing. The usual size of block is 8 by 8 by 16 inches. If blocks have to be shipped any great distance, the cost is likely to be prohibitive.

In building a block silo, care must be taken to have sufficient reinforcing, sound blocks, and good mortar joints. If the joints are not waterproof, leakage will occur, causing spoilage of the silage next to the walls, and the silage juices will cause rapid corrosion and failure of the reinforcing.

When block walls are started the blocks should first be laid around the footing in a true circle, beginning at the doorway with a full block and ending at the opposite side of the doorway with a half block. All mortar joints should be of equal thickness. The blocks are then

bedded in place in mortar. The amount of reinforcing indicated in table 8 should be placed (fig. 22) between courses as they are laid up, care being taken to break the joints by one-half block, keeping each course directly above the former course in a true circle and the face of the wall plumb. Mortar should be made of 1 part cement and 2 parts sharp clean sand, with not more than 10 percent as much lime as cement added to make it workable.

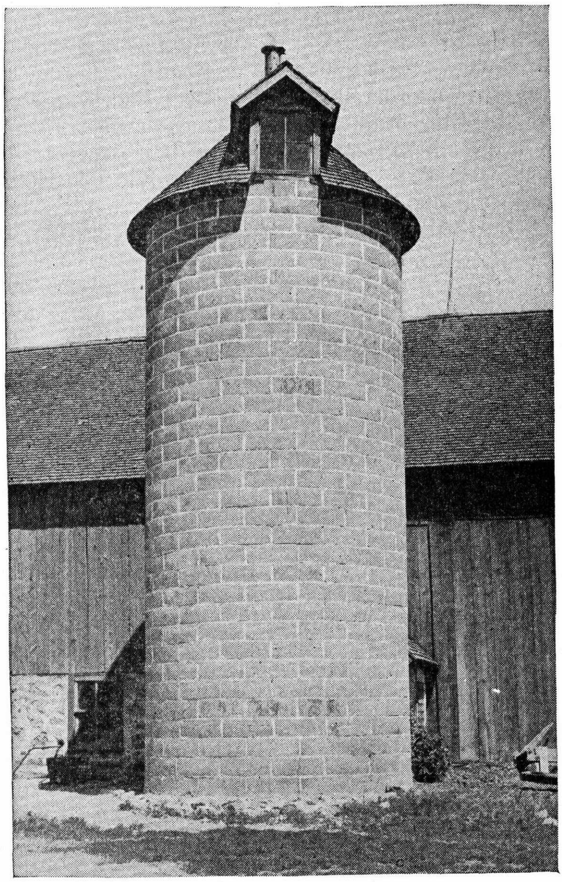

FIGURE 21.—Concrete-block silo.

The chute may be made of wood, metal, or concrete blocks. A wooden chute (fig. 31) is fastened to the silo by means of 2- by 4-inch pieces bolted in place along each side of the doorway with bolts set in the concrete of a continuous doorframe or in the mortar joints between courses. A metal chute is bolted on in the same way. In a block chute the blocks can be bound to the wall by blocks or with metal ties and either run down to the floor level or supported by an I-beam level with the plate of the feed room.

TILE SILOS[2]

Tile silos (fig. 23) are built of hard burned or glazed tile especially molded to fit the curve of the wall. When well-constructed of sound tile, they are very durable and require little upkeep. The doorway is generally continuous, and the jambs are usually built of poured concrete or of special jamb blocks. The special blocks have a 2-inch rabbet along the inside edge to receive the doors. Vertical reinforcing is placed through openings in the jamb blocks and the horizontal rods, used in quantities given in table 8, are attached to the vertical ones. All these reinforcing rods must be well embedded in mortar. The wall should be laid out and built up as described under concrete-block silos. All reinforcing must be covered with mortar and the joints well filled to make the silo waterproof and to protect the reinforcing iron from corrosion. The manufacturers of silo tile furnish construction directions, and some of them will contract to build the silo. Chutes can be built like those in concrete-block silos.

BRICK SILOS

Good hard-burned brick are suitable for silos if they can be obtained at a reasonable cost and laying is not too expensive. Cull paving brick have been used in many instances to good advantage. These silos are built with either single or double walls. The single wall 4 inches thick is the most common, since it requires less material and labor.

Manufactured doorframes, ladder rungs, and bolts to go with fabricated reinforcing bands can be purchased. The fabricated reinforcing is in the form of flat corrugated bands curved to fit the size of silo desired. If such reinforcing is not available rods or wire can be used in the amounts recommended in table 8. The reinforcing is placed between courses, spaced to give the necessary strength. When a high silo is built and the reinforcing required per foot of height is large, it is better to use smaller wire or rods in each course or in alternate courses than to increase the size of the mortar joints to care for heavy reinforcing.

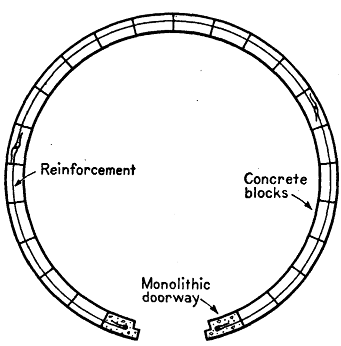

FIGURE 22. — Method of placing reinforcing between courses. Note how the rods are anchored to the vertical reinforcing at the doorway.

Chutes made of brick are most desirable. They are bonded to the silo wall with metal ties or brick and supported on steel I-beams. Metal or wood chutes may also be used, such as those described under concrete-block silos. Detailed instructions for building brick silos may be obtained from the Brick Manufacturers Association, Cleveland, Ohio.

[2] A detailed description of the construction of tile silos and specifications for the blocks can be found in Iowa Station Bulletin 189, Silo Construction, obtainable from the Department of Agricultural Engineering, Iowa State College, Ames, Iowa, for 6 cents.

WOOD-STAVE SILOS

Of the various woods available, redwood, cypress, longleaf pine, white pine, cedar, and Douglas fir are generally considered best for silo staves. Creosoting will make less-durable woods more resistant to decay and reduce shrinkage and swelling due to moisture changes.

TYPES OF STAVES

Wood-stave silos are generally built of milled tongue-and-groove staves. This type is undoubtedly the most satisfactory, although

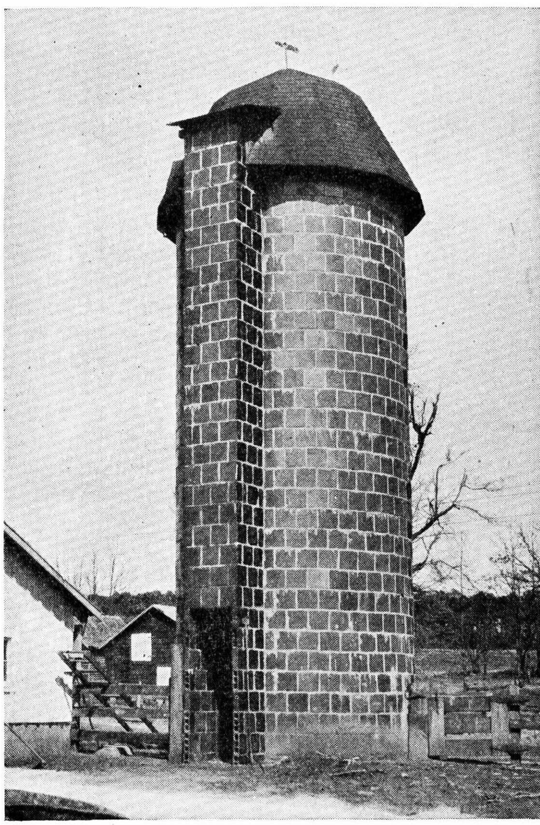

FIGURE 23.—Tile silo with tile chute.

many silos built with square- or slightly bevel-edged staves have also given satisfaction. Where good, well-seasoned 2- by 4-inch or 2- by 6-inch lumber is available at low cost the square-edged stave silo can be erected at a lower first cost than most other types. They are erected like other stave silos except that the staves are nailed together every 4 or 6 feet as illustrated in figure 24.

Tongue-and-groove stave silos are generally purchased as a complete unit including staves, hoops, doors, roof, and anchoring materials. Care should be taken to see that the staves are of good quality and that sufficient hoops (table 9) are furnished.

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The silo should be bolted to anchors set in the foundation (fig. 3), from four to nine anchors being used depending on its size. Where high winds are likely, additional anchorage should be provided, with cables fastened to the top of the silo and run to anchors in the foundation or to anchors set a few feet away from the foundation. Where the silo is built close to the barn two or three such anchors will suffice.

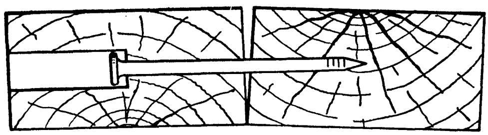

FIGURE 24.—Splicing staves together.

It is preferable that each stave be in one piece, but if this is impossible, the staves should be of two pieces of different lengths, splined together by making in the ends to be joined a saw cut 1 inch deep and parallel to the sides of the stave and inserting a galvanized sheet-iron spline, as shown in figure 25.

CUTTING THE DOOR STAVES

Before the staves are put up it is necessary to decide how many doors the silo should have and make saw cuts halfway through one of the staves to be put up in the doorway location for the entrance of a handsaw in cutting out the doors after the staves are in place. The cuts should be made at a slant of 45° on the edge of the stave and horizontal on the front, as shown in figure 26, so as to make the doors removable only toward the inside. The cut for the bottom of each door should slant downward from the outside of the stave, and that for the top should slant upward.

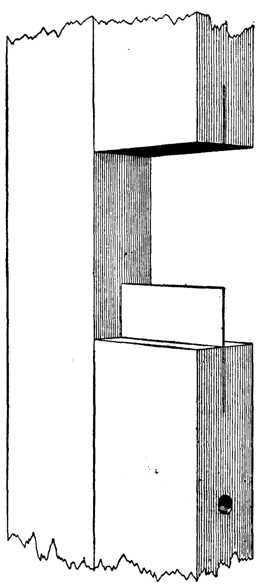

FIGURE 25.—Splicing wood staves.

To prevent this stave from being broken in handling, a slat should be nailed on one side of it. This slat should be removed after the stave has been put in position.

When the staves are being put up, the partly cut door stave should be placed at one side of the place where the doors are to be cut. The doors are sawed out after the hoops are put on.

SETTING UP THE STAVES

The first stave should be placed with its inner face on a line drawn on the foundation wall 2 inches from its inside edge, plumbed on the face and edge, and securely braced at top and bottom. Braces are nailed to stakes driven firmly into the ground or to some adjacent building, as shown in figure 27. If this is not carefully done the silo will be out of plumb.

In setting up spliced staves the longer and shorter staves should alternate. Ordinarily it will be necessary to have staves of only two lengths, for instance, 16 feet and 12 feet for a 28-foot silo. When all the hoops are in position they should be tightened until the staves

are pressed close together. Staples should then be driven over each hoop 2 or 3 feet apart to hold them up in case they get loose.

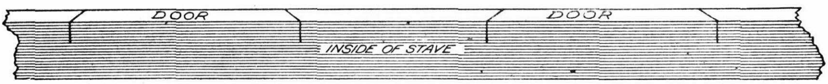

FIGURE 26.—First stave with door cut started to allow the entrance of a saw when set up.

Care must be taken to tighten the hoops of a stave silo to prevent storm damage or collapse as the staves dry out when the silo is empty.

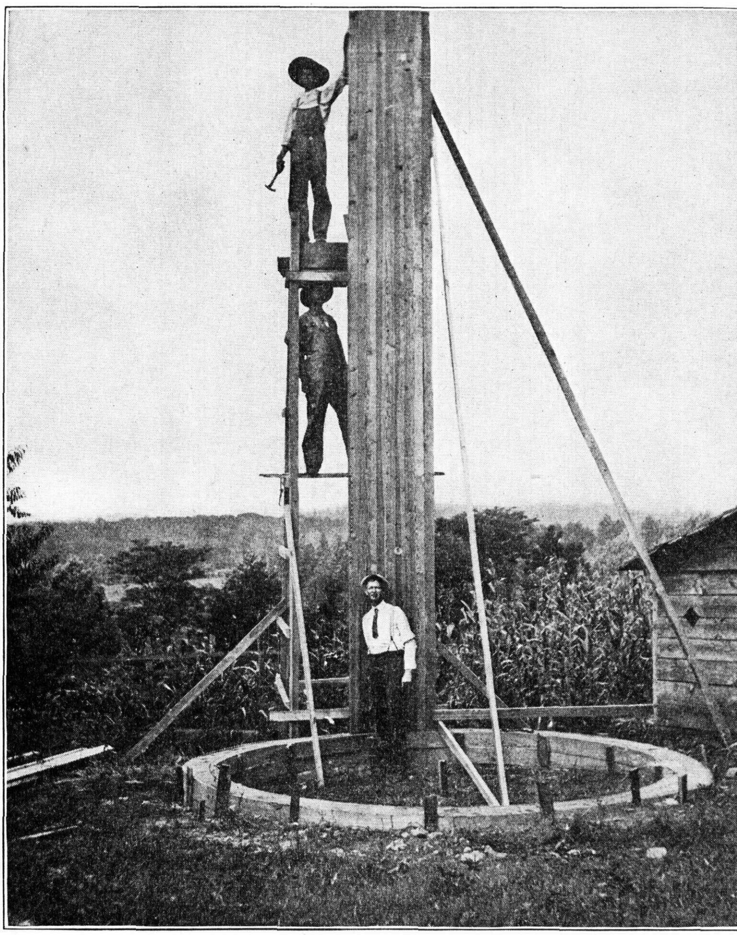

FIGURE 27.—Setting up the staves.

They should be loosened as the silo is filled to prevent crushing as the staves swell from absorbed moisture.

JOINING HOOPS WITHOUT LUGS

It is sometimes very difficult to get lugs for the hoops. In such cases 4- by 6-inch timbers may be put in instead of ordinary staves at from two to four points where the hoop sections will join. These timbers should be placed with the 4-inch face flush with the staves on

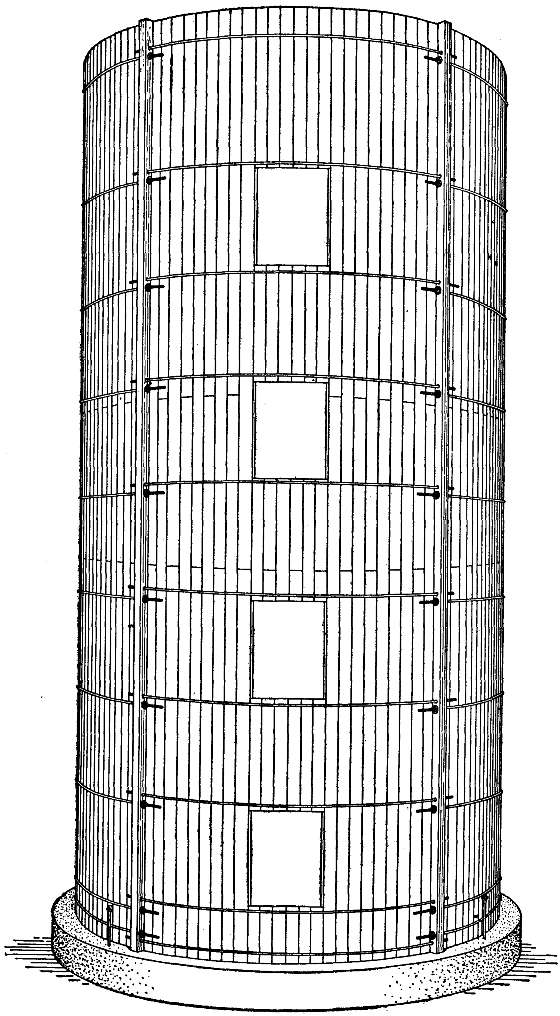

FIGURE 28.—Joining hoops without lugs.

the inside. They will extend 4 inches beyond the wall on the outside. Through these outside projections holes should be bored to receive the hoops, and the ends may be fastened with nuts over large iron washers. Such a method of connecting hoops is shown in figure 28, but its use is advised only when the lugs cannot be obtained.

DOORS AND DOORWAYS

After all the hoops are tightened, saw the doors out, beginning with the stave previously cut. Two cleats, 2 by 4 inches, with one edge cut to the circle of the silo, should be nailed and bolted on the outside of each door (fig. 29) with the nuts on the outside and the bolt heads sunk flush with the inner surface. The bolts should be 3/8 by 5 inches.

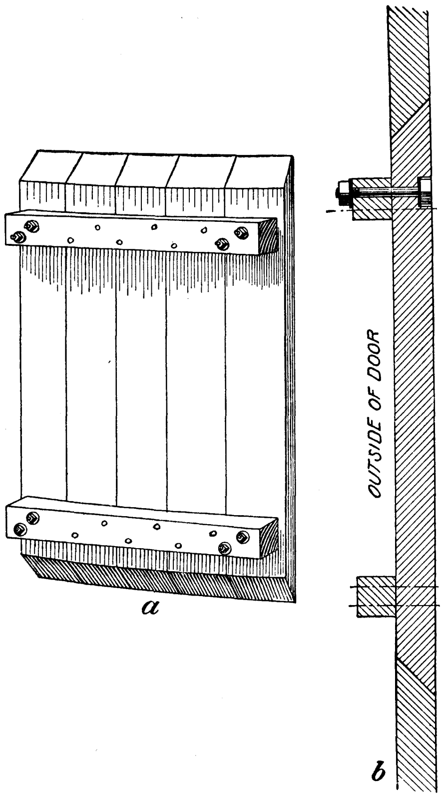

FIGURE 29.—The finished door: *a*, Door showing outer surface and cleats; *b*, section of wall showing how door fits.

Four bolts in each cleat (two at each end) will be sufficient. The cleats may be nailed to the other strips.

To construct a continuous doorway for a stave silo, a frame should be made of 4- by 6-inch timbers, which are kept 20 inches apart by means of pieces of pipe and fastened together with bolts passing through the posts and pipes, as shown in figure 30. The holes for the spacer bolts should be drilled through the doorposts with the same vertical distance between them as the hoops are to have. The hoops should cross the door opening not more than 2 or 3 inches from the spacers so as not to obstruct the door opening. Iron washers should be placed between the timbers and ends of the pipe. Washers should also be used under the bolt heads and nuts.

When the doorframe is complete, it should be put in position, plumbed, and securely braced, after which the staves should be put up, as previously described. The doorposts should be flush with the staves on the inside. On the outside they will project beyond the staves, and holes for the hoops should be bored in these projections.

Doors for this frame are made of two thicknesses of tongue-and-groove flooring with acidproof building paper between, the inside flooring running vertically and the outside horizontally. The doors

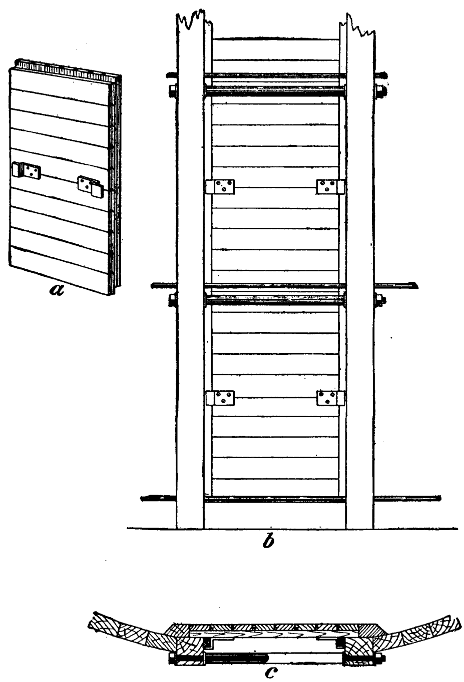

FIGURE 30.—A continuous doorway: *a*, View of door; *b*, doorframe with door in position; *c*, cross section showing door and doorframe.

may be held in position by means of iron straps, one on each side, which projects over a slat nailed to the doorpost. When the silage is to be used, the topmost door is taken out, which makes room for sliding up the other doors as the silage is fed out. The doors may be held up by pins placed in holes in the posts.

As shown in figure 30, the doors are so made as to overlap where they meet and thus make a tight joint.

CHUTE

A chute is built over the doors, as shown in figure 31. The simple 2- by 4-inch framing is merely spiked to the staves. Where the silo has intermittent doors a ladder is built on one side of the chute.

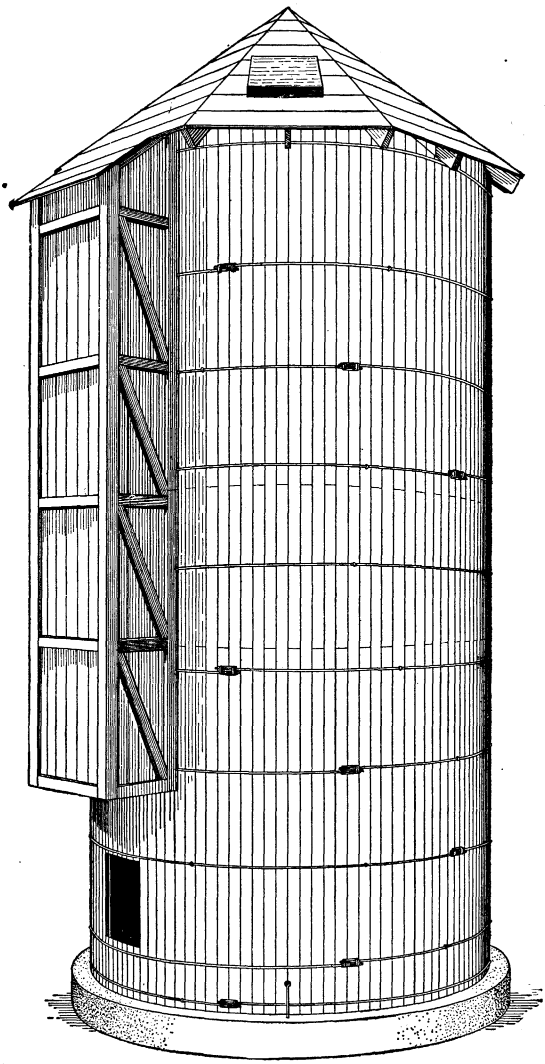

FIGURE 31.—Complete stave silo with chute.

THE MODIFIED WISCONSIN SILO

REQUIRES NO METAL REINFORCING

The modified Wisconsin silo, built of studs and horizontal sheathing, requires no metal reinforcing. The ½-inch sheathing is bent to the circle formed by 2- by 4-inch studs, spaced 1 foot on centers, and acts as a hoop to resist the silage pressures. Rough lumber of random lengths can be used for this type of silo, which makes possible low-cost construction in regions where local lumber is available.

FOUNDATION

The foundation for the modified Wisconsin silo is constructed the same as that for a stave silo. Instead of eyebolts, anchor blots 16 inches long should be used. These should be embedded in the foundation wall 5 to 6 feet apart and 3 inches from the inside edge, extending 5 inches above the top of the wall.

SILLS AND PLATES

The sills and plates are formed of two thickness of 2- by 4-inch pieces, 2 feet long, with the ends beveled to form a circle. The proper bevel may be determined in the following manner: From the center stake used in laying out the foundation wall draw a circle on top of

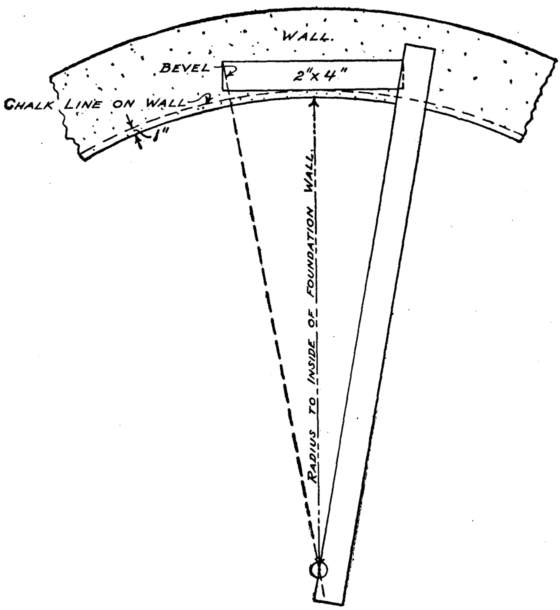

FIGURE 32.—Method of obtaining bevel ends for sill and plate.

the foundation wall 1 inch from the inside edge (fig. 32). At any point on this line lay a 2- by 4-inch piece 2 feet long, with both ends at equal distances from the center; then use a slat with one edge on the center point of the stake and let the same edge on the other end of the slat strike the outer corner of the 2- by 4-inch piece. A line drawn along the slat across the 2- by 4-inch piece will give the proper angle or the bevel. The same process will give the bevel for the other end.

Use this piece as a pattern in cutting pieces enough to form the double circle for both sill and plate. The number needed will depend on the diameter of the silo. After cutting several pieces, lay them along the wall, note how they fit, and make any necessary changes. When all the pieces are cut lay them out on the wall along the line 1 inch from the inside edge of the wall, boring the necessary holes for the anchor bolts. On this layer place the second course, breaking the joints, and boring the holes. Next cut the same number and size of

pieces to be used for the top plate and lay aside until needed. Then spike the two rings of the sill together and tighten the nuts on the anchor bolts.

DOORPOSTS

It is preferable to set the doorposts before the studs are placed, so as to avoid trouble in getting the door in just the right place. The doorposts should be 4 by 4 inches and long enough for the height of the silo. If not, they may be spliced by halving and bolting (fig. 33). Set them up to the line 1 inch from the inside edge of the foundation wall, leaving a 24-inch space between. Toenail securely to the sill. The openings for the doors are made by nailing in headers and sills at the

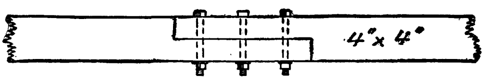

FIGURE 33.—Splicing doorposts.

places where the doors are desired, leaving the spaces open when the inside sheathing is put on. For the size of the openings, see figure 34.

STUDDING

The size of the studding is 2 by 4 inches, and if the pieces are not long enough for the height of the silo they can be spliced with 1- by 4-inch pieces 4 feet long, nailed on each side over the joint (fig. 35). Whenever it is necessary to splice the studs the pieces should be of different lengths, such as 12 feet and 16 feet for a 28-foot silo, and in setting the studding the long and short pieces should alternate.

It is preferable to do the splicing before the studs are placed in position. When all are spliced and cut to equal length they should be placed 1 foot apart from center to center, with the edge 1 inch from the inner edge of the foundation wall, or in line with the circle previously marked out in laying the sill, and then toenailed to the sill. Great care should be taken to have the studs plumb on all sides and well braced to the inside scaffold so that the top of the silo will form a circle. The pieces to form the plate can be nailed on as the studs are set, laid in the same way as the sill, and nailed firmly to the tops of the studs.

At least two hoops formed from the thin sheathing should be nailed around the outside of the studding to keep them from bulging while the sheathing is being nailed on. These hoops can be removed after the sheathing has been placed on the inside.

SHEATHING

The sheathing, of ½- by 6-inch material, is put on from the bottom up. To prevent uneven bending, the joints should some on different studs. At the door openings the lining is cut back 1 inch from the inside edges of doorposts to form a rabbet for the door (fig. 34.)

Two layers of the sheathing are put on the inside with acidproof building paper between (fig. 34). The lining will be stronger if the cracks and joints in the first layer do not come opposite those of the second. It is more convenient if these two layers are carried up with the one on the studs just far enough ahead of the others to give room for putting on the paper.

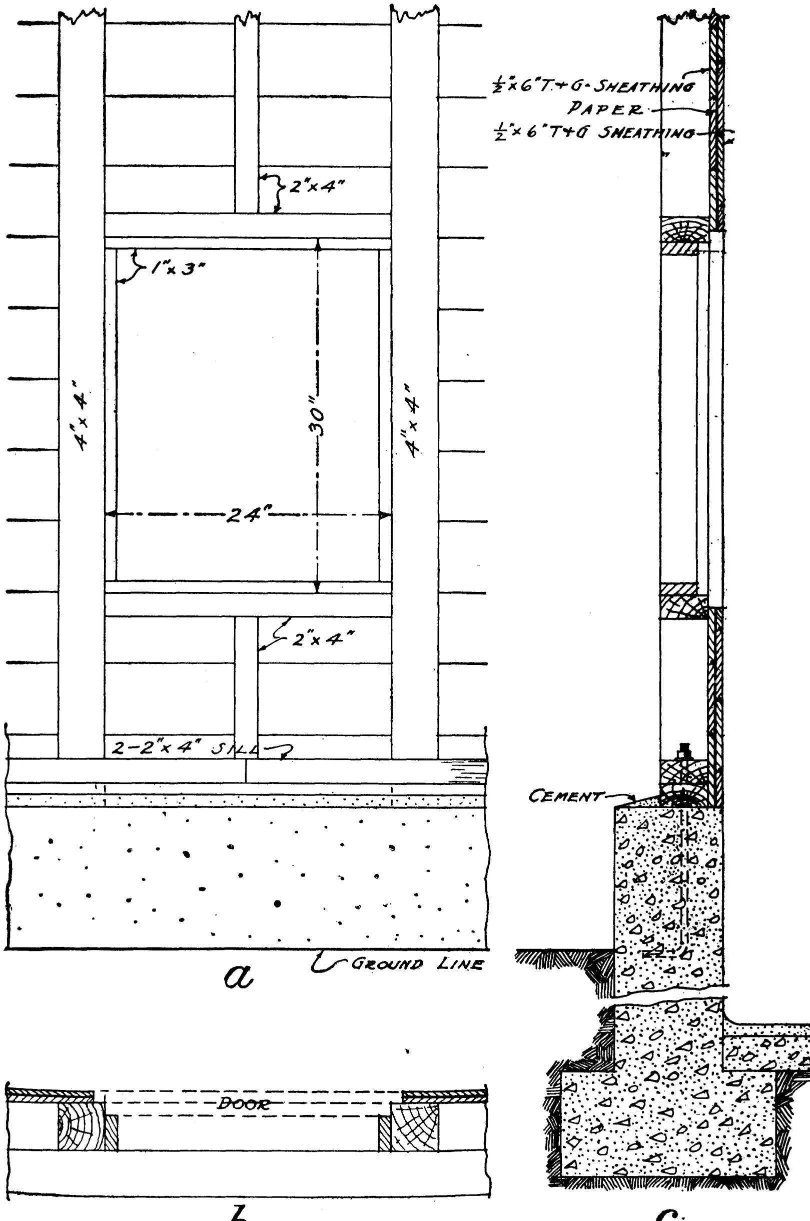

FIGURE 34.—Details of construction of modified Wisconsin silo: *a* and *b*, details of door opening; *c*, sectional view of foundation and wall.

FIGURE 35.—Splicing studs.

DOORS

The doors are made of two thicknesses of 1- by 6-inch tongue-and-groove flooring, the inside layer vertical and the outside horizontal, with acidproof building paper between (fig. 36). A 1- by 3-inch strip

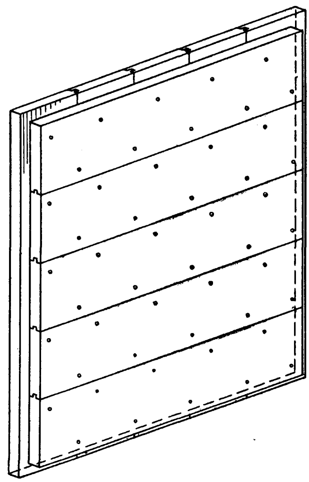

FIGURE 36.—Door for modified Wisconsin silo.

is then nailed around the door openings 1 inch from the inside of the studs to form the jambs.

THE WOODEN-HOOP SILO

THIN BOARD HOOPS AND SHEATHING USED

The wooden-hoop silo is made with hoops of thin boards lined with tongue-and-groove sheathing placed inside the hoops and, often, with moisture-resistant paper between. This sheathing may be 1 or 2 inches thick, preferably 2 inches. Short lengths of milled staves are often used, shorter than can be used in regular stave silos.

ANCHORAGE

Four to six anchors, of $\frac{3}{8}$- by $1\frac{1}{2}$-inch strap iron 46 inches long, with the lower ends bent out 2 inches, should be embedded in the foundation wall. Two holes for half-inch bolts should be drilled in these irons, one 2 inches and the other 24 inches from the upper end. The anchor irons (figs. 3 and 38) should be placed in the foundation wall $2\frac{3}{4}$ inches farther from the center of the silo than the inside of the silo wall, with the lower hole 4 inches above the foundation, so they can be bolted through the two lower hoops to the silo wall.

BUILDING THE FORM FOR HOOPS

The hoops are made on a form. First, drive a 2- by 4-inch stake and saw it off 1 foot from the ground. Fasten one end of a strip a few inches longer than the radius of the proposed silo to the top of

this stake with a tenpenny nail. Measure from the nail 1 inch longer than the radius of the silo, and cut the strip off at this point. One inch toward the center from the outer end of the strip, drive a 1- by 4-inch stake about 20 inches long, swing the strip halfway around the circle and drive a similar stake in line with the first and the center stake; swing the strip quarterway around and drive a third stake, and place a fourth stake opposite the third stake. Drive additional stakes (fig. 37) around the circumference so that the spaces between stakes are about 2 feet. Fasten to these stakes 2- by 4-inch uprights about 6 feet long, with their outer edges plumb and flush with the end of the measuring strip. When all the uprights are in place remove the

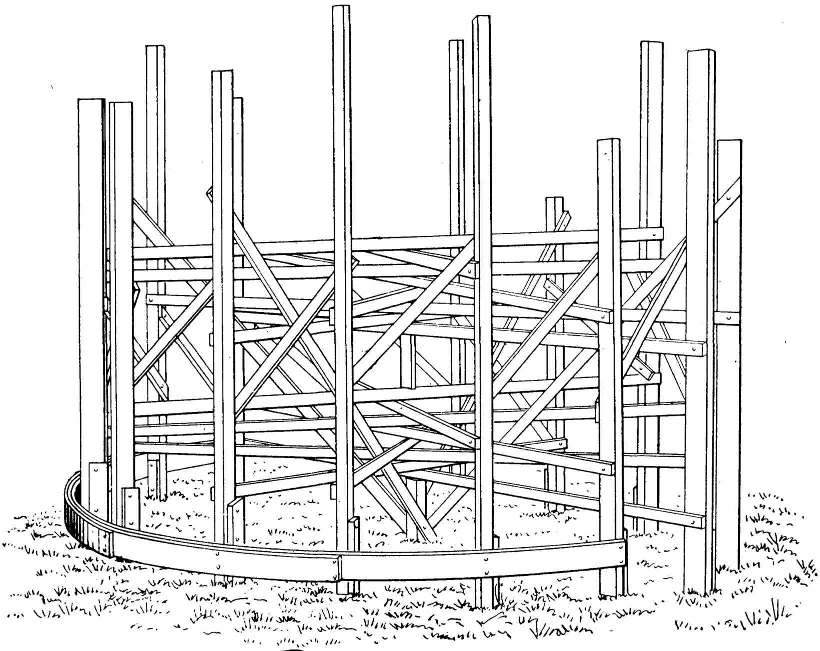

FIGURE 37.—Form for building hoops for wooden-hoop silo.

measuring strip. Tie opposite uprights at the bottom with 1- by 1-inch strips of edging material cut to the exact diameter of the form, which is the same as the outside diameter of the silo wall. These strips should be marked in the middle, the lowest one nailed at this point to the top of the center stake and the remainder nailed to each other at these marks. Beginning about 4 feet from the ground, tie the upper parts of the uprights in the same way. The uprights should be plumbed and braced to each other, and about four braces should be run from the uprights to the center stake.

MAKING THE HOOPS

The hoops are made of 4-inch oak, elm, ash, pine, or chestnut strips ½ inch thick or a trifle thinner. They are usually made three-

ply, except for silos of the larger heights and diameters, for which four-ply hoops are used. Make a mark on the outside face of one of the uprights about 6 inches above the ground. Level around from this mark with a carpenter's level, marking each upright. The marks indicate the position of the upper edge of the first hoop. Now fasten one end of the hoop material (fig. 37) to one of the uprights, so that it will bend around the form to the left; nail it to each upright with the upper edge flush with the mark. At the third upright begin the second ply of the hoop, at the sixth the third ply, and bend the boards around the form, nailing to each upright with eightpenny nails, and between the uprights and at the joints with sixpenny nails. Break the joints. Butt joints in the outer layer should be carefully fitted. Start the second hoop on the next stud to the left of the place where the first hoop was started, and continue as before. The number of hoops required is one-half the height of the silo, in feet, plus 1. Thus, a 30-foot silo requires 16 hoops.

When all the hoops are completed they are numbered from the bottom up, and perpendicular lines are drawn in four places to assist in plumbing the hoops when raised in position. The form is now torn out and all nails in the hoops clinched. All joints in the outside layer of each hoop should be covered with pieces of galvanized iron 12 inches long, nailed with galvanized brads to protect the joints from the weather. The hoops are next placed on the foundation in the same order and position as on the form, with one of the perpendicular lines immediately on the left of the proposed door opening. The scaffold is now erected so that the hoops may be placed in position.

SPACING THE HOOPS

On the ground splice four staves, each equal to the height of the silo, and mark on them the spacing of the hoops. The mark for the first hoop should be 6 inches from the bottom of the stave, the next three marks are spaced 23 inches, and the remainder 24 inches, except the last two, which are spaced 23 inches. These staves are now placed in position on the foundation, each one flush with one of the perpendicular lines drawn on the hoop, and are nailed temporarily to the bottom hoop. The top hoop is now raised with ropes and nailed in position to the tops of the spacing staves and supported by 2- by 4-inch pieces attached to the scaffold. The remaining hoops are raised and fastened to the spacing staves in their proper positions. The hoops are then plumbed at the spacing staves, starting on the left of the proposed door opening, and braced to the scaffold.

PLACING THE STAVES

The first stave is carefully plumbed and nailed on at the left of the door opening. Nail the staves on as flooring is laid (fig. 38), driving the tongue into the groove and blind nailing, to each hoop with two nails. Break the joints in adjoining staves, and make all joints on hoops. Plumb the edge of the staves about every 5 feet around the wall, and continue nailing the staves on until the opposite side of the

door opening is reached. The temporary spacing staves are removed as the sheathing of the wall progresses to them. The opening left should be about 35 inches wide to allow for fitting in the doorjambs and doors 24 inches wide. Bolt the silo to the foundation (fig. 38),

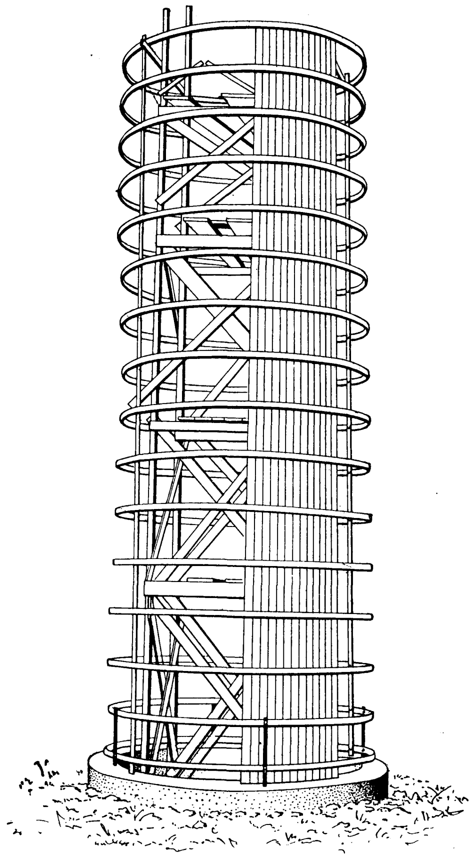

FIGURE 38.—Wooden-hoop silo started with scaffolding, hoops and several staves in place.

running ½- by 3¼-inch bolts through the staves, hoops, and anchor irons.

DOORJAMBS

Cut pieces of 1- by 4-inch lumber 35 inches long, bevel the ends to fit the inside curve of the hoops, and nail the ends of one of these pieces across the opening on the inside of the upper hoop and one on the inside of the lower hoop. The remaining pieces are similarly fitted and placed in position on the hoops, carefully plumbed and nailed into place (fig. 39). These pieces form stops for the tops and bottoms of the doors. After these crosspieces are in place, nail an additional stave on each side of the opening. Next prepare two other staves for the doorjambs by removing the tongue from one of them and

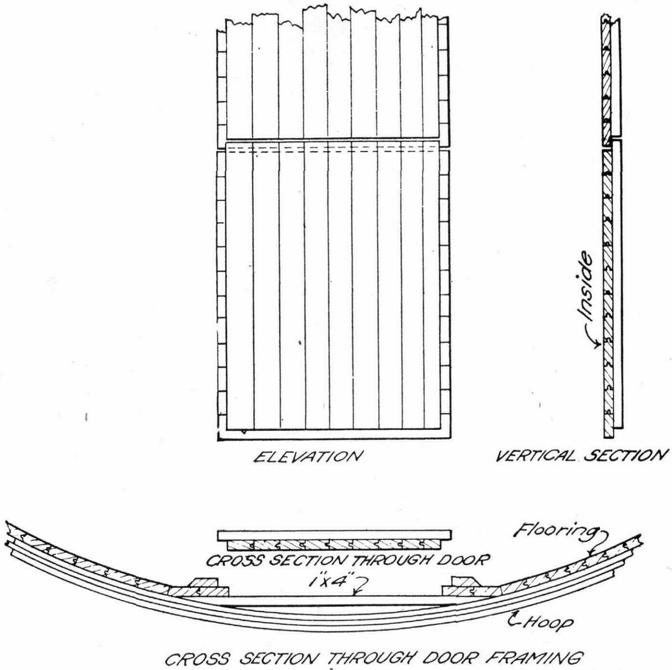

FIGURE 39.—Details of door and doorway for wooden-hoop silo.

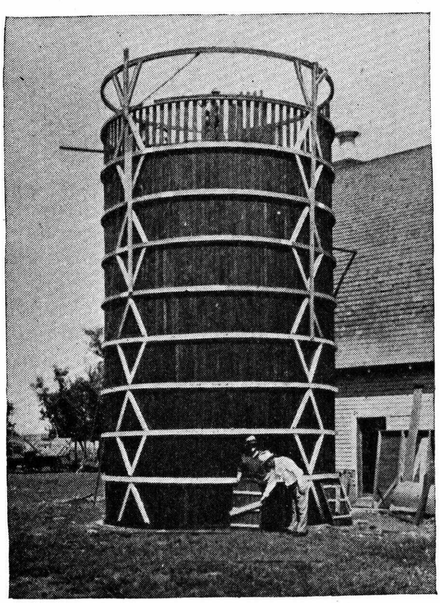

FIGURE 40.—Wooden-hoop silo of short staves, almost complete.

the groove from the other and fasten them into place on each side of the opening. Care should be taken to see that the finished door opening is of uniform width from top to bottom. On the inside of the doorjambs and 1 inch back from the edges of the door opening, fasten 1- by 3-inch strips the back edges of which are beveled toward the wall.

Figure 40 shows a wooden-hoop silo made with short staves with braces between the hoops.

TIMBER-CRIB SILOS

ROUGH-CUT LUMBER PREFERRED

The timber-crib silo (fig. 41), built of 2- by 4- or 2- by 6-inch lumber and lined with boards or plaster may be economical in timber regions

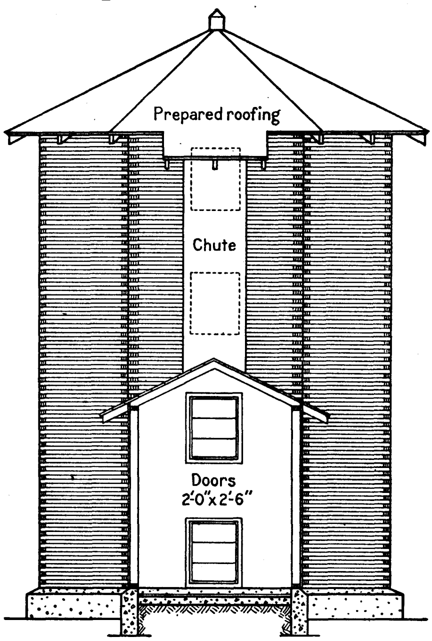

FIGURE 41.—Architect's drawing of a timber-crib silo.

or where farm-cut lumber is available. It requires little skilled workmanship. It should not be built of green lumber as shrinkage will crack or loosen the lining. Rough-cut lumber is best when the lining is to be cement plaster, since the uneven edges and cracks hold it to the walls. If smooth lumber should be used, metal lath or wire cloth would be needed to support the plaster, but finished lumber is uneconomical in this type of silo. Timber-crib silos should have six or eight sides, each side not more than 6 or 7 feet wide. A six-sided silo 6 or 7 feet to the side has a cross-sectional area about equal to that of a cylindrical silo 10 or 12 feet in diameter.

CONSTRUCTION

It is best to make a pattern for the cribbing pieces first, since the foundation wall will be the same shape as the superstructure. The

ends are cut to an angle of 60° to the long side of the piece for a six-sided and 45° for an eight-sided silo. The pattern can be laid out with a carpenter's square, as shown in figure 42.

After the pattern is made, it can be laid on the leveled site of the silo and the foundation marked off and built as described on page 8. Anchor bolts can be set in the foundation wall to which the bottom two or three layers of cribbing can be bolted. The successive layers

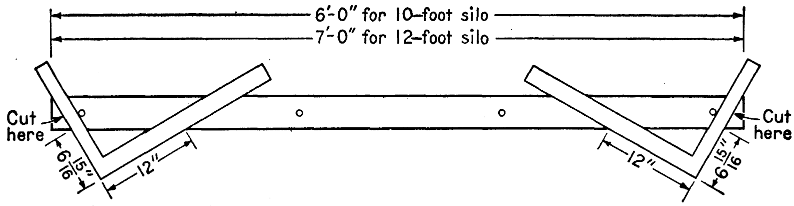

FIGURE 42.—Laying out a pattern for cribbing.

of cribbing are spiked to the preceding layer with twentypenny nails, alternately lapping the end joints (fig. 43). Careful spacing of nails around the door opening will save much trouble when the doorway is to be cut out.

The door openings, in the middle of one side, can be cut out as the wall is built up, each cut-out being made when the wall reaches the level of the top of each door. The doorframes of 2- by 6-inch plank are placed to extend inside the silo the thickness of the inside

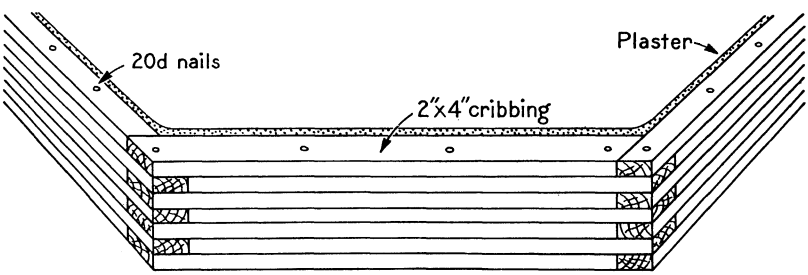

FIGURE 43.—Laying up cribbing.

lining and are securely spiked. The 1- by 2-inch door-stop strips are nailed to the frame 2 inches from the inside edge.

FINISHING THE INSIDE

The inside surface of the wall can be finished with tongue-and-groove sheathing, flooring, or cement plaster. The corners are covered as much as practicable. Cement plaster is the most suitable and lasting. The plastering should be done in two coats, the first about one-half inch thick, the next one-quarter to three-eighths inch thick. For the first coat use 1 part cement to 2 parts clean sharp sand and one-eighth bushel of plaster hair to each barrel of cement. Hydrated lime or lime putty made by slaking lump lime is generally added to make the plaster work easier. The lime added to each batch should not be more than one-tenth the amount of cement used. The second

coat should be applied before the first coat has dried and should be mixed 1 part of cement to 2 parts sand. The wall is finished with a concrete wash, as is a monolithic concrete silo.

The outside can be finished with siding, vertical boards and bats, or plaster, or it can be left plain. Unless the silo is to be built higher at a later date, it is best to cover the outside at once.

METAL SILOS

Metal silos are easy to erect. It is necessary to keep the inside painted with a refined tar or asphaltic preparation to prevent corrosion by silage acids. They must be firmly anchored and guyed to avoid wind damage while empty. In cold climates silage in metal silos freeze more readily and to a greater depth than in most other silos. These silos can be purchased complete in many parts of the country. The manufacturer may erect the silo, or the purchaser, with the help of two or three handy men, can do the work himself.

BELOW-GROUND SILOS

Silos with all or most of their storage capacity below the ground level have been successfully used in the semiarid regions of this country for many years. They fall into two groups, the pit silo and the trench silo. The pit silo is circular in form, dug as deep as desired or as the ground-water level will permit. It may have a curbing extending several feet above the ground. This type is popular in the Southwest and in other regions where the soil is firm and dry and the ground-water level is low. The trench or modified trench silo came into use 25 or 30 years ago and is now found in most sections of the country. If good drainage can be provided, it can be built in any section where the ground-water level is 3 feet or more below the surface. It has been used successfully in Mississippi, where the annual rainfall is about 60 inches.

PIT SILOS

Pit silos are not liable to storm or fire damage and in dry climates preserve silage as well or better than above-ground silos because of the uniform soil temperatures. The capacity of a pit silo is the same as that of a round above-ground silo of the same dimensions, and the required size should be governed by the factors previously discussed. Especial care must be used in entering pit silos since suffocating gases often accumulate in them.

LOCATION

In many soils it is impracticable and even dangerous to dig a deep pit, hence the farmer should know the character of the soil before attempting to construct a pit silo. The soil must be well drained, so that water will not stand in the bottom, and of such a nature that it will not readily cave. Soils containing large rocks are not satisfactory for pit silos, as the walls are likely to be defaced and weakened when the rocks are removed. Any firm, well-drained, and comparatively dry soil, free from seeps, rocks, and sand strata should be satisfactory. Where pit silos have not been tried, the farmer should observe the water table in a nearby well. If this is not possible, it is advisable to

bore some 2-inch holes with a soil auger or pipe to the depth of the proposed silo and learn the character of the soil. The maximum height of ground water in the test holes will indicate the lowest point to which a pit silo should be dug.

If possible, the silo should be near the feed lot or barn, but the edge of the pit should be at least 6 feet away from the barn wall. In no case should the silo be so located that it will receive seepage or drainage water from barns, feed lots, or manure pits since contamination from these sources might result in the spread of disease.

CONSTRUCTION

A curb or collar 4 to 6 inches thick around the top of a pit can be laid out and constructed the same as an above-ground silo foundation wall

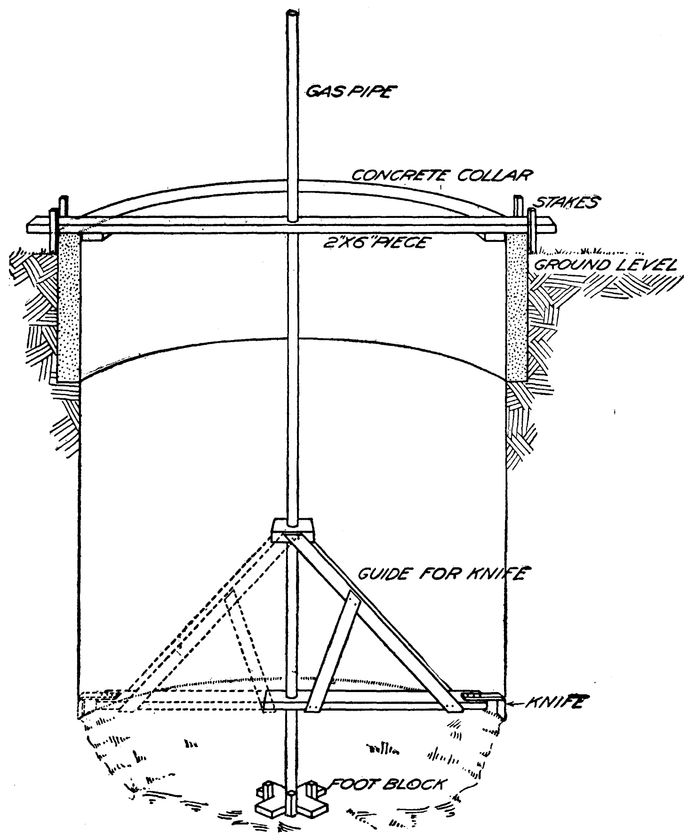

FIGURE 44.—Vertical section of a pit silo, showing device for keeping the walls smooth and plumb.

(figs. 1 and 3), omitting the footing and anchors. A wall about 4 feet high is built on the concrete curb. This may be of concrete, lumber, concrete blocks, hollow tile, or brick. Woven-wire fencing has been used for this purpose; if this enclosure is well made it will keep persons or livestock from falling in, and the space enclosed can be filled with

silage. Forms are necessary for building a concrete wall, which should be about 4 inches thick and reinforced with heavy woven-wire fencing or other reinforcing.

If a carrier of the overhead-track type is to convey the silage away from the silo, it should be erected while the curb is becoming set and before the pit is dug. The carrier can then be used to remove the soil from the pit. The hoisting apparatus can be used to lift out the soil, but it will pay to use a horse or team to lift it.

After the concrete curb has set well—in about 3 days—the pit may be dug. Remove the soil, digging straight down from the inside of the curb. Be sure to keep the wall perpendicular and smooth. If the wall slopes inward, the silage will settle away, leaving an air space, and some silage will be spoiled.

Several devices have been used to aid in keeping the wall straight and smooth. A simple plumb line is most often used, and a straightedge made from a 1- by 4-inch piece, used in connection with an ordinary carpenter's level, assists in keeping the wall both plumb and smooth. Figure 44 illustrates a device which has been used in the Southwest. The stakes next to the curb and the blocks nailed on the lower surface of the 2- by 6-inch piece are put in place before the digging of the pit is started. The hole in the 2- by 6-inch piece, through which the pipe passes, is bored directly over the center of the silo. After each section of the pit is dug, the 2- by 6-inch piece is put in place, and a plumb line is dropped through the hole to locate the exact center in the bottom. Then the foot block is staked in place, and the pipe lowered through the 2- by 6-inch piece, through the guide, and into the hole in the foot block. The guide is then revolved, and the knife shaves the wall smooth or indicates irregularities in the wall. When the wall has been smoothed to the approximate level of the foot block, the apparatus is removed, this section of the wall plastered, and digging is then begun for the next section. This is repeated for each 5- or 6-foot section excavated.

In soils not too sticky when wet, digging will be made easier if enough water is run in at night to soak the ground. When rocks are encountered they should be removed without blasting, if possible. In case blasting is done, no one should enter the pit after the blast until the air and poisonous gases have been replaced by fresh air. A limb of a tree, or a blanket, or the bucket used to lift out the soil may be used on a rope to agitate the air for a few minutes.

When the removal of rocks destroys the smooth surface of the wall the defacements should be repaired by the use of metal lath or similar material. The metal lath or mesh should cover the damaged area and extend well out over the solid wall, and be secured with long, iron pins, so that it is flush with the surrounding wall. Large holes may be partly filled with concrete before being covered with the lath. Adobe mud, where available, is often used for this purpose.

LINING THE PIT

When 5 or 6 feet have been excavated, the wall should be plastered about 1 inch thick with a mortar of 1 part cement and 2 or 2½ parts of clean, sharp sand. Two coats will be required to do this, and at least 2 hours should elapse between the applications. However, the second coat should be applied before the first has become completely dry. A

lining 1 inch thick is sufficient in some soils, but in soils not very firm a 1½- to 2-inch coating on the wall is safer. In any case it should be reinforced with woven wire or metal lath. It will be found desirable to start the lining an inch or so below the curb and leave this band bare until the silo is completely dug. This will allow the curb to settle without buckling or cracking the lining below.

Before a plaster lining is applied the wall should be dampered to prevent the dry soil from absorbing moisture from the mortar too rapidly. Before the plaster is set, apply with a whitewash brush one or two coats of a wash of pure cement and water, mixed to a creamy consistency. The application of this last coat assists in making the wall stronger, smoother, airtight, and almost waterproof. Keep the wall damp for several days, as this will help the plaster to harden properly and make the wall stronger.

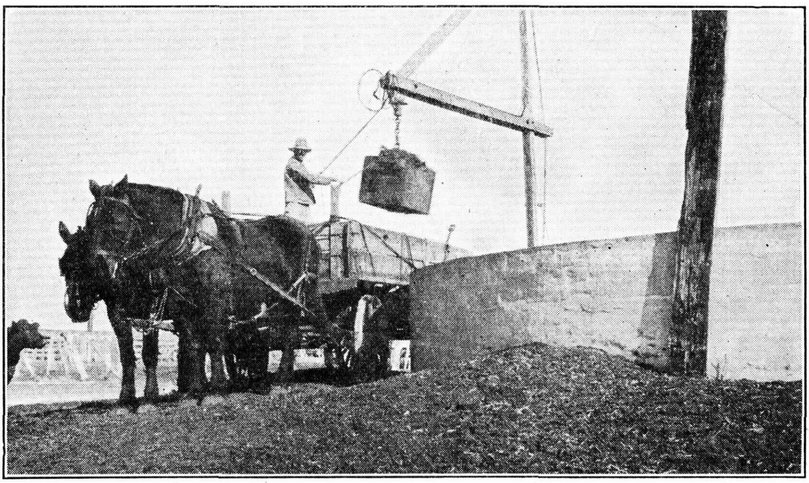

FIGURE 45.—Equipment for removing silage from a pit silo.

After the first section of 5 or 6 feet has been lined with the mortar and cement wash, digging may be resumed, and so on until the desired depth is reached. In this way the danger of caving and the necessity of building scaffolding for the application of the lining are eliminated. Linings of concrete, brick, tile, or stone can be used as described on page 56 under trench silos. Such linings may vary from 4 to 8 inches in thickness.

An inexpensive covering of some sort should be placed over the silo. A simple board roof is sufficient. A space of about 2 feet or more should be left at the top of the wall to allow for free circulation of air, which makes less probable the accumulation of gases. However, there is always need for caution where these gases can accumulate. See warning on inside of front cover.

Where a man furnishes all his own labor, obtains sand and gravel at a small cost, and installs a home-made hoisting apparatus, a pit silo of considerable capacity can be constructed at small cost, as the only cash items would be cement and wire mesh or metal lath.

HOISTING DEVICES AND FEEDING EQUIPMENT

The problem of hoisting and feeding silage from pit silos is not difficult. Practically all the devices now in use are inexpensive home-made affairs. One of the most successful and simple types is illustrated in figure 45. It consists of a swinging crane, pulleys, rope and

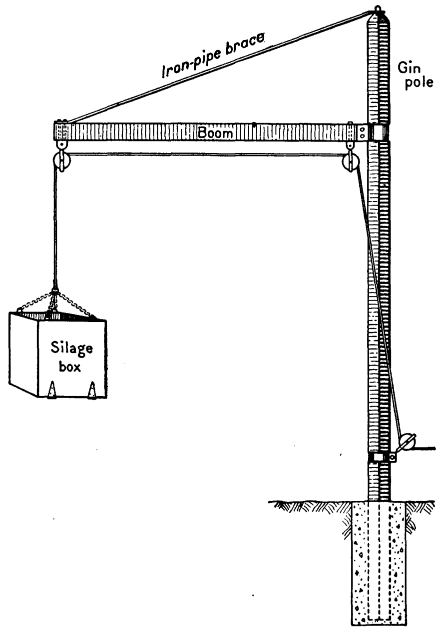

FIGURE 46.—Hoisting device for removing feed from a pit silo; the mast should be a 6- by 6-inch timber for 500 pounds of silage and the boom 4 by 4 inches. If it is desired to remove 1,000 pounds at a time the mast should be an 8- by 8-inch timber.

a box for the silage. A 6- by 6-inch piece may be used for the upright or mast, and a 4- by 4-inch piece for the boom. Only sound timbers should be used. The upright should be braced from the top with heavy guy wires securely anchored. Figure 46 illustrates a mast and the different members of a hoisting device that does not require guy wires. A horse may be used to lift the silage. The silage box after being filled and hoisted can be swung over a wagon or attached to a trolley on an overhead track, or placed upon a truck or wagon and hauled to feed bunks or mangers. Such a hoisting device may be so placed that it can be used to empty two or even three silos. The silage box should have a trip bottom, end, or side so that it may be unloaded easily.

Figure 47 shows how a regular hay carrier and outfit is used to lift and feed silage from a pit silo. The track can extend into the barn or in front of the feed bunks.

A farmer should install a hoist and feeding equipment that conform to his particular needs, keeping in mind the desirability of convenience, durability, and safety.

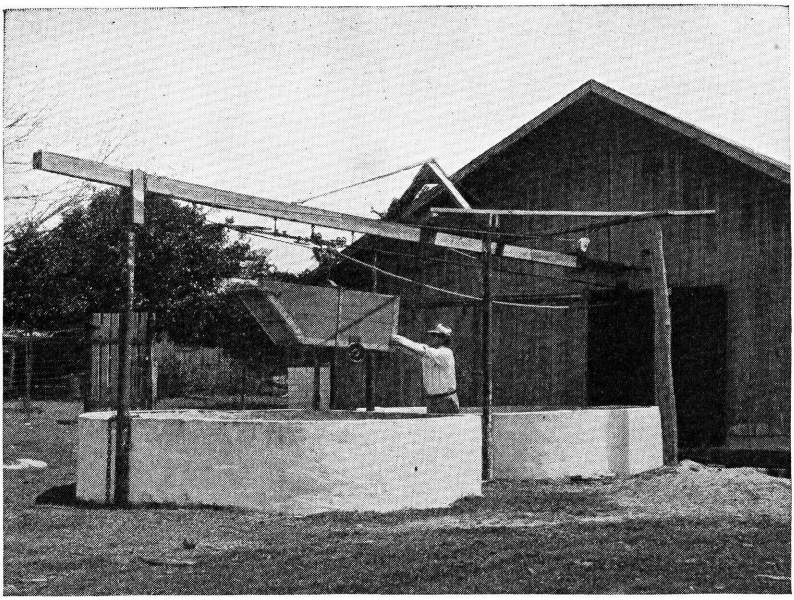

FIGURE 47.—Twin silos with a hay carrier and hoist for removing silage.

TRENCH SILOS

The trench silo has many advantages. Unlined, it can be made for labor cost only, so that often a tenant farmer can afford to make one. With the use of a team or tractor, it can be made quickly in emergencies. The repairs are limited to smoothing the walls and cleaning drains. It is adaptable to small herds and can be filled with a small cutter, with or without a blower. This type affords easy access to the silage. It can be built as a temporary silo and lined for permanent use later.

A disadvantage is that there is considerable spoilage, ranging from 5 to 25 percent. Also, unless lined, the side walls tend to cave, and when rain occurs during the feeding season, the bottom of the trench may become muddy and make entrance to the trench so difficult as to require a temporary road of planks. Special care is necessary in packing the silage, and suitable drainage must be supplied if the site does not have adequate natural drainage. The open trench is dangerous unless fenced or roofed, and it is not easily filled in when abandoned. Special care must be taken to guard against suffocating gases in the bottom of a trench silo, especially when it is in level ground. See the warning on the inside of the front cover.

SIZE, CAPACITY, AND COST

The cross-sectional area of a trench silo should be proportioned to the size of the herd and weight of silage to be fed daily. (See table 1.) The length can be adjusted to suit the amount of silage required for a given feeding period, allowance being made for from 5- to 25-percent spoilage. Where the silo is unlined and is to be used each year, the cross section should be made small enough to allow for trimming and

evening the sides before filling without increasing the capacity beyond the daily feeding requirements.

Normal corn silage in a trench, well-packed by tractor or animals, should average from 30 to 40 pounds per cubic foot. In table 11, which gives dimensions, areas, and capacities, the density assumed is 35 pounds per cubic foot. When the silage is to be fed during cold weather only or in very cold climates, the cross-sectional area can be increased and only 2 or 3 inches fed per day.

TABLE 11.—*Dimensions, cross-sectional area of trench silo, and weight of silage in 4-inch layer and per lineal foot*

Side slope per foot of depth (inches)	Depth	Bottom width	Top width		Cross-sectional area	Weight of 4 inches of silage	Weight per lineal foot
	Feet	*Feet*	*Feet*	*Inches*	*Square feet*	*Pounds*	*Pounds*
3	4	5	7	0	24	280	840
4	4	6	8	8	29	338	1,015
5	4	7	10	4	33	385	1,155
3	6	6	9	0	45	525	1,575
4	6	7	11	0	54	630	1,890
5	6	8	13	0	63	735	2,205
3	8	6	10	0	64	747	2,240
4	8	7	12	4	77	898	2,695
5	8	8	14	8	91	1,062	3,185
3	10	6	11	0	85	992	2,975
4	10	8	14	8	113	1,318	3,955
5	10	10	18	4	142	1,657	4,970

The only cost of constructing unlined trench silos is the labor. The time required to dig out a trench will depend on the size, type of soil, and the equipment used. Two men with a team and slip scraper should move about 20 cubic yards in an 8-hour day in heavy clay soils and 30 cubic yards in light clay or loam. If a trench 7 feet wide at the bottom, 11 feet wide at the top, and 6 feet deep is to be dug, and 45 tons of silage is to be stored, a trench 50 feet long will be needed, allowing for a 5-percent spoilage, and the approximate time can be estimated as follows: Table 11 gives the cross-sectional area as 54 square feet. Multiplying this by the length (50 feet) and dividing by the number of cubic feet in a cubic yard (27) gives 100 cubic yards as the quantity of earth to be moved. If the soil is a heavy clay about 5 days of 8 hours would be required, and if a light soil about 3 days. Lining the walls makes the cost much higher. In the silo mentioned, the slant height of the wall is 6 feet 4 inches. If allowance is made for an 8-inch footing and a 6-inch curb, the total wall needed would be 7 feet 6 inches high. Multiplying the 7 feet 6 inches by 50 (the length) and by 2 (two sides) gives 750 square feet of wall. Seven hundred and fifty square feet of 4-inch concrete wall would require 750 times one-third, or 250 cubic feet (9.26 cubic yards) of concrete. Two hundred feet of 45- or 48-inch hog wire would be needed for reinforcing. Concrete usually costs from $8 to $12 per cubic yard in place. For this type of wall a form 10 to 20 feet long can be built and moved along the trench as the sections are completed. Estimates of wall linings of other types can be based on the number of square feet of wall required.

LOCATION

A trench silo should be as convenient as possible to the feed lot or barn, yet where it will not interfere with farm operations, be unsightly,

or receive seepage or drainage from barns, feed lot, or manure pit. A hillside or slope is desirable because one end may open level with the ground surface, facilitating the removal of silage and allowing water entering the trench to drain out. Drains should be made around the trench to intercept surface water. Where only level ground is available, the trench should be dug with sloping ends to permit driving in and out during construction, filling, and feeding. Where the ground is impervious, a drain can be run from the lowest part of the trench to a dry well or to lower ground to take care of water trapped in the trench when partially or entirely empty. In some cases water is drained to the lower end of the trench and bailed out. Figure 48 illustrates lay-outs for trenches dug under different conditions of topography and drainage.

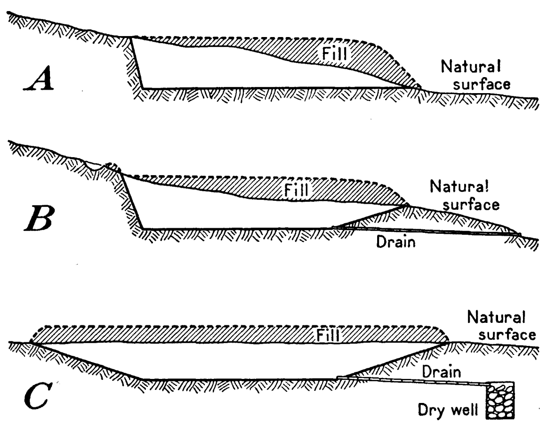

FIGURE 48.—Lay-outs for trench silos under different topographical conditions: *A*, On a hillside; *B*, on a gentle slope; *C*, on level ground.

DIGGING THE TRENCH

After the trench is staked out, the ground is plowed (fig. 49), but not so near the stakes as to prevent the smoothing down of the side slope. The loose ground is then removed, generally with a slip or fresno scraper (fig. 49), and another layer plowed. These operations are continued until the desired depth is reached. If the earth removed from the trench is placed along the sides, the ground at the sides will slope away from the trench, and the depth of the trench below the natural level of the ground will be reduced. Doing this reduces the drainage of surface water into the trench.

The sides may be trued and kept to slope as the trench is dug, or this can be done after the bottom of the trench is reached. A spade and mattock or grubbing hoe may be used for this purpose.

Another method, especially for emergency use, is to dig the trench very shallow and when filling it, stack the silage several feet above ground, covering it with dirt from the trench. In some European countries metal forms about 2 feet high are used to hold the silage while the dirt is being banked around it. The forms are raised as the mound is built up, and the top is finally covered with earth. This has the advantage of requiring only a shallow trench, but more labor is required to cover the mound.

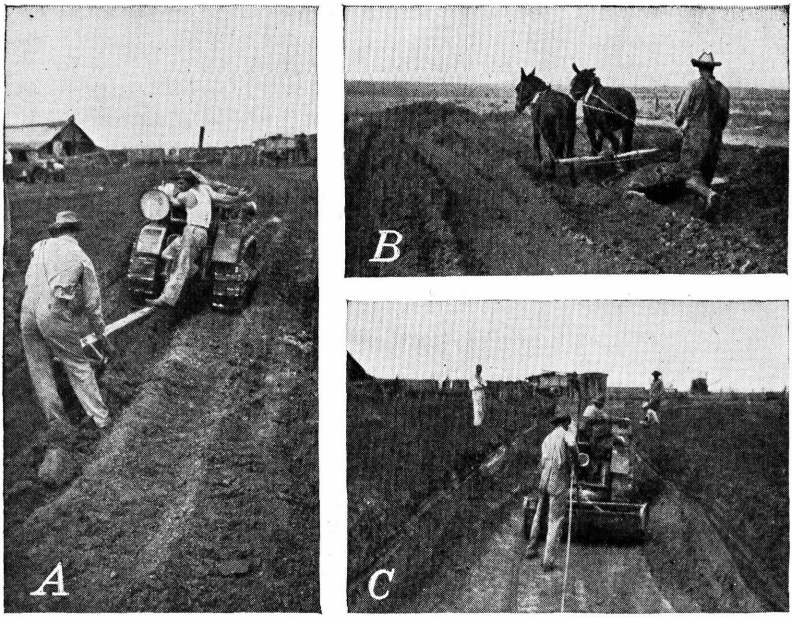

FIGURE 49.—Digging a trench silo: *A*, Plowing; *B* and *C*, removing the soil.

Regardless of whether the trench is to be lined or not, the sides should not slope more than is necessary for the type of soil. A slight slope keeps the silage tight against the sides as it settles but too great a slope will hinder settling. Trenches have been dug with walls ranging from vertical to almost 45° slopes. Slopes of from 3 to 5 inches per foot of depth, as noted in table 11, are recommended. If a slope of much more than 5 inches to the foot is required to make the side walls stable, they should be lined.

When the trench silo is not to be lined, the edges must be protected against caving. Posts can be set at regular intervals and planks or poles placed along the edge. A fence must be built to keep persons and animals from falling into the trench.

If the trench is to be lined later, the cross section should be a little smaller than the final silo desired, to allow for truing the walls after use. The allowance will depend on the stability of the soil.

It is probably more important to line a trench silo intended to be filled and emptied each year than one used to carry over feed from good years to lean, since most wall weathering occurs when the trench is empty. If the trench is to be used to keep feed for several years, it should be well drained to avoid excessive spoilage.

TYPES OF LINING FOR TRENCH SILOS

Walls of trench silos can be lined with cement plaster, concrete, rubble masonry, brick, tile, or wood (fig. 50). Wood linings are not very lasting unless creosoted and are not economical except where local lumber is plentiful.

Where soil conditions are good, cement plaster makes a good lining if 2 or 3 inches thick and reinforced with wire mesh. The wire mesh is fastened to the wall with spikes or iron pins. A plaster made of 1 part cement to 3 parts sand and 3 parts crushed stone or pea gravel is suitable and should be applied in horizontal strips from 12 to 15 inches high to prevent sloughing. Horizontal boards as wide as the lining is thick, placed on edge about 2 feet apart along the walls of the trench can be used to level the surface of the lining. One strip should have time to set before a second is applied. A finishing coat of plaster mixed 1 part cement and 3 parts sand is applied with a trowel. A cement wash may also be applied. Where a stronger wall is desired, a concrete lining 4 to 6 inches thick can be placed by using forms and reinforcing, as shown in figure 50, *B*.

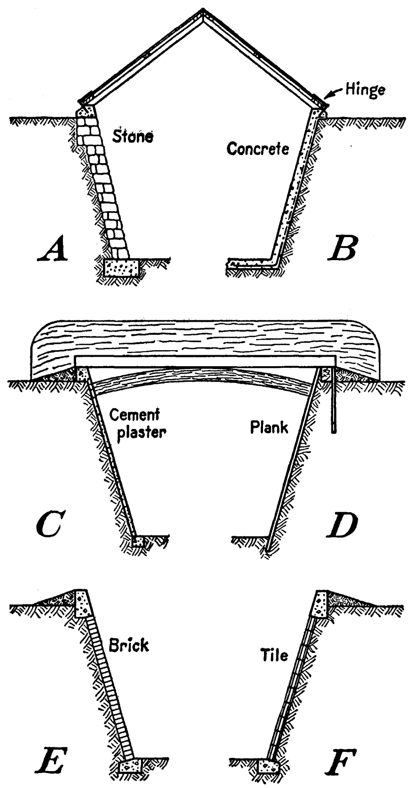

FIGURE 50.—Different types of lining and roofs for trench silos: *A*, Stone; *B*, concrete; *C*, cement plaster; *D*, plank; *E*, brick; *F*, tile.

In localities where native stone is plentiful, a rubble masonry wall can be made at low cost except for labor. The wall should be from 12 to 16 inches thick, it should be laid up with a cement mortar made of 1 part cement to 6 parts of sand, and the surface should be covered with from one-half to three-fourths inch of 1:3 mix of cement plaster (fig. 50, *A*). If dressed stones are used, the wall can be built 8 inches thick with a 1:3 cement mortar. Brick and tile can be used in the same manner (fig. 50, *E* and *F*). Where there is any danger of the earth

walls sliding, reinforcing rods can be placed between courses from 18 inches to 2 feet apart, and the slope of the wall flattened to 5 inches per foot of depth.

Where the ground-water level is close to the surface and the trench silo is extended above ground by banking (fig. 48), care must be taken to make the wall lining strong enough to prevent cracking.

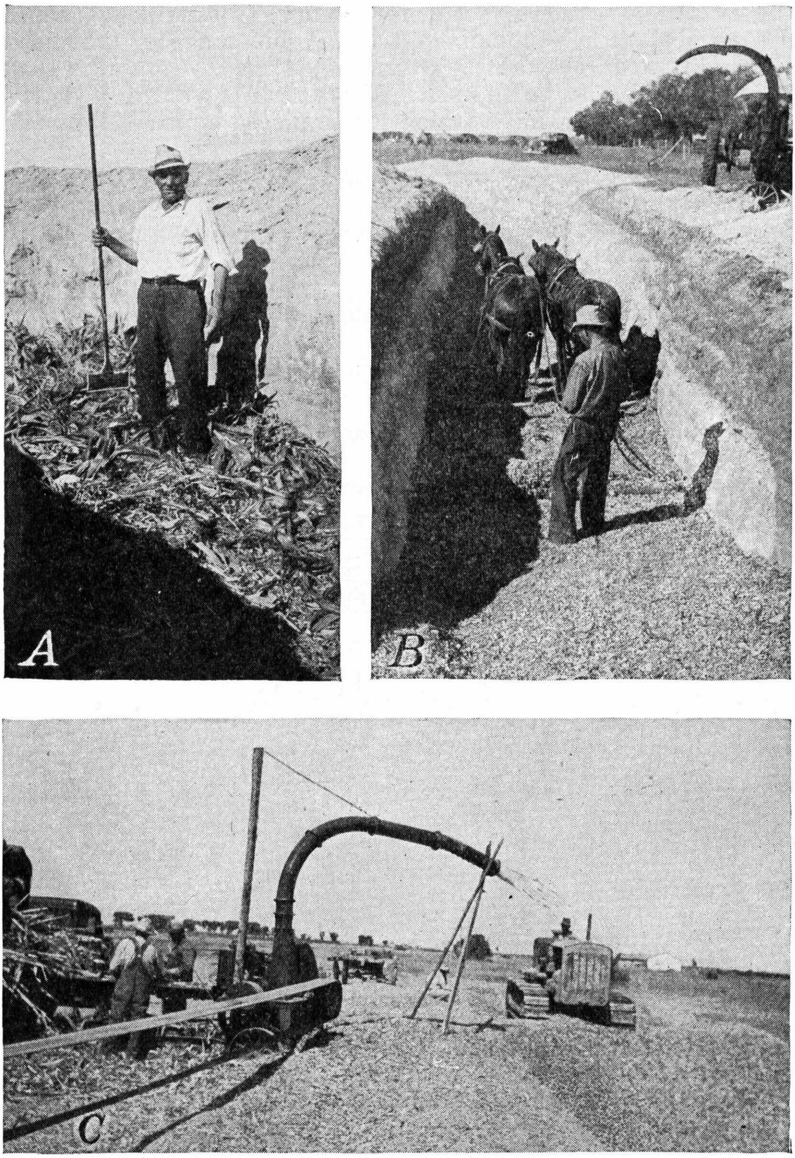

FIGURE 51.—Filling and packing a trench silo: *A*, Knife for chopping out uncut silage; *B*, using team to spread and pack silage; *C*, packing with tractor. Note that the silage is above grade.

A trench silo may be filled with either cut or uncut forage (fig. 51, *A* and *B*). If the silage is uncut, the cost of filling is less, but removal requires more labor. However, with a knife similar to that shown in figure 51, *A*, the stalks may be cut and easily removed. When a trench silo is filled it should be packed by a team (fig. 51, *B*) or a tractor (fig. 51, *C*) and heaped from 2 to 4 feet higher than the trench to allow for settling. In the South, the top is usually covered with straw, weeds, or rakings, wet down, and a layer of earth from 4 to 6 inches deep (fig. 52) added. In the North, because of snow and freezing

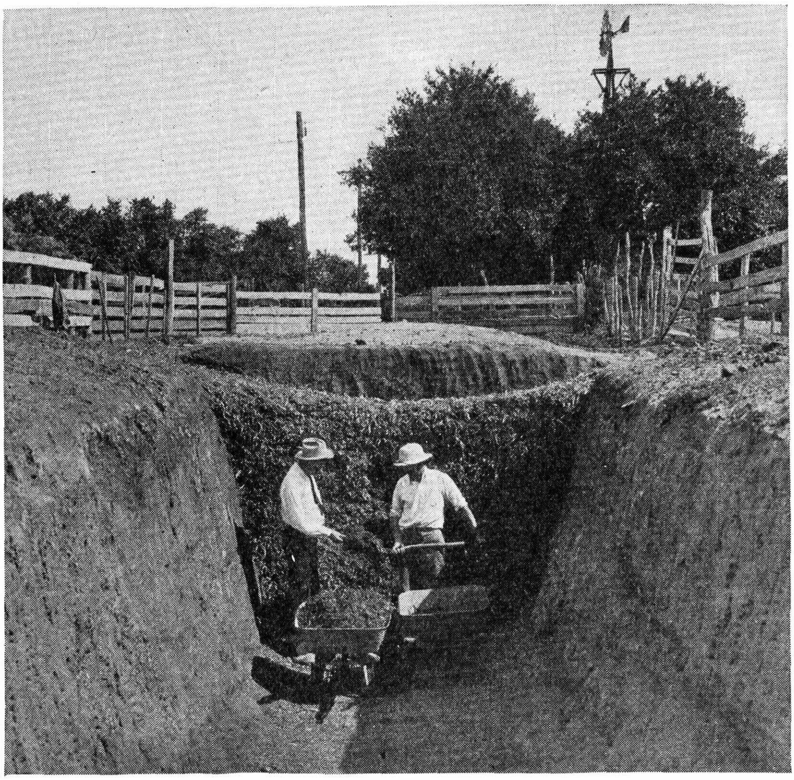

FIGURE 52.—Opened trench silo, showing how soil was used as a covering.

weather, a roof is desirable. Using straw, hay, or stalks will give protection against freezing (fig. 50), but roofs of wood frames covered with boards or sheet metal are more serviceable. They may be made in sections which can easily be removed or hinged to swing back along the top of the trench.

If the silo is not to be opened for a long period, it should be inspected regularly and any cracks that have formed in the covering filled with dirt. Silage has been kept in good condition for 12 years in unlined trench silos.

TEMPORARY SILOS

Silos of woven wire, picket fencing, or snow fencing are used throughout the country to meet emergencies and to supplement

permanent silos. They are low in cost, can be erected on short notice when drought or bumper crops make them needful, and require no doors. There are few records of the capacities of temporary fence silos. Those reported indicate that the height is generally about the same as the diameter and that the capacities are within the ranges given in table 12.

TABLE 12.—*Materials required for different sizes of lined fence silos and approximate cost*

Size of silo		Capacity	Fencing [1]			Length of No. 9 wire [2]	Paper [3]	Cost of material
Diameter (feet)	Height		Pieces	Length of each				
	Feet	*Tons*	*Number*	*Feet*	*Inches*	*Feet*	*Feet*	*Dollars*
12	12	15 to 18	3	38	3	250	138	21
14	16	28 to 34	4	44	6	375	208	30
16	16	38 to 44	4	50	10	435	236	35
18	20	76 to 88	5	57	1	600	325	47
20	20	90 to 105	5	63	6	665	350	52

[1] If slat or snow fencing is used these lengths should be measured after the wire has been stretched.
[2] 2 hoops for each width of fencing.
[3] 4 feet wide.

FENCE SILOS

Fence silos may be built with or without a lining. Snow fence and rectangular-mesh wire having vertical stays 2 inches apart probably give the best results. The slats or vertical wires keep the fence from buckling as settling occurs, and the upper and lower rings slide onto each other readily.

All kinds of building and roofing papers, with and without fibrous reinforcement, may be used as lining. Reinforced papers give better results. Some papers are treated to resist acid and certain bacterial action. According to tests conducted by the Bureau of Dairy Industry, lining reduces spoilage more than half. In a South Dakota survey of 40 silos, 18 of which were unlined, the loss around the walls of the unlined ones varied from 5 to 18 inches of silage and averaged 10.5 inches. In lined silos it ranged from 2 to 18 inches of silage and averaged 8.3 inches. The loss in individual silos ranged from 4.41 percent to 42.7 percent.

Table 12 lists the materials required for lined fence silos. In addition to the items shown in the table, some spring clothespins will be needed to hold the lining to the sides while filling the silo. Some ¼- or 5/16-inch turnbuckles to tighten the wire are desirable.

The circumference of the silo is laid out on ground as nearly level as obtainable in a good location, as described under laying out foundations (p. 8). The site should then be leveled. Set up the fencing in a true circle and securely fasten the ends together. Place the lining on the inside of the fence so the edge folds in along the bottom and clamp it temporarily to the top of the fencing strip with clothespins or other clamps. This section can now be filled within 6 inches of the top. The second section is then placed and held in position temporarily by binding the slats together about every 18 inches with twine. The bottom lining is placed inside the second course of fencing, and the lining for the second tier is placed so as to lap over

the inside of the bottom strip. This prevents the fence from tearing the lining as the silage settles. The second section is filled to half its height. Then two No. 9 reinforcing wires are put around the first tier, pulled taut, and twisted together or fastened with small turnbuckles. Turnbuckles are inexpensive and make it easier to handle and salvage the wire. The twine used to hold the second tier of fencing in place may now be removed to allow it to settle freely inside the first tier. Other tiers are handled in the same manner till the silo reaches the desired height, usually not less than three nor more than six tiers. Generally the height of an unsupported fence silo should not exceed its diameter. If it is built more than one tier higher than this, it should

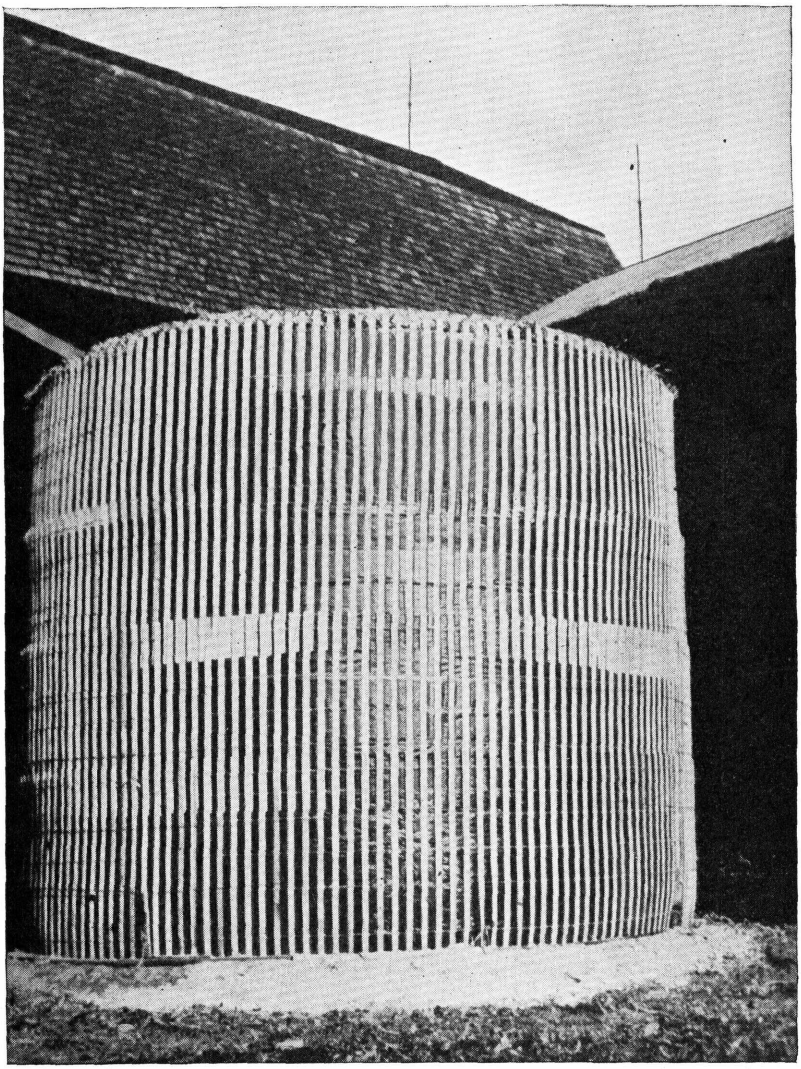

FIGURE 53.—Temporary fence silo.

be surrounded by from 5 to 10 poles 6 to 8 inches in diameter firmly set in the ground. The poles are set against the silo walls and may be tied to each other above the silo with No. 9 wire and anchored for wind bracing, but in no case should the walls of the silo be fastened to them. Figure 53 shows a well-constructed snow-fence silo lined with reinforced paper. Note that the earth removed to level the building site is outside the silo, where it will not affect the even settlement of the walls.

STACK SILOS

If roughage is plentiful, stack silos can be used in emergencies if the prospect of a high percentage of loss does not preclude their use. Either cut or uncut roughage can be stored in them. If not cut, the roughage is simply stacked in the most desirable form. Since losses occur principally around the outside of the stack, the larger the stack

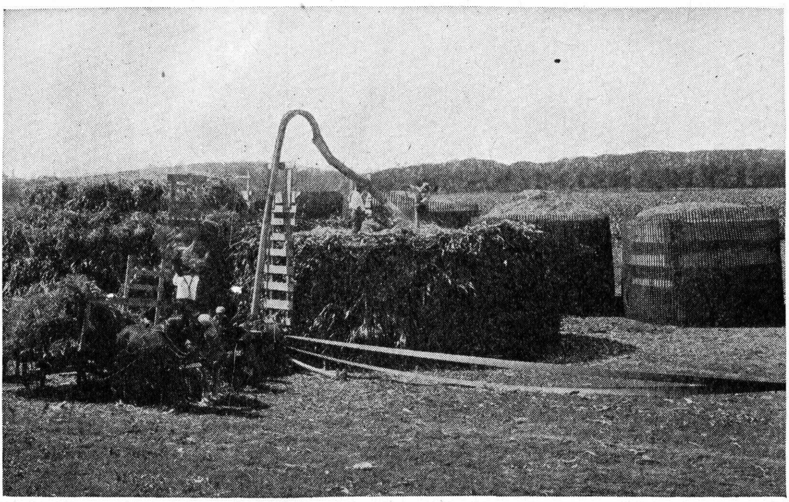

FIGURE 54.—Filling a corn-bundle silo with cut silage. Note the fence silos in the background.

the smaller the percentage of loss. The stack should be packed as tight as possible to exclude air. It is best to feed out this type of silage by slicing layers off one end of the stack with a hay knife. When a cutter is available the cut material can be placed in a shell formed by bales of hay or straw, corn bundles (fig. 54), or loose weeds or grass. This method results in less spoilage and the silage is much easier to feed.

When bales of hay or straw are used for a silo they should be tied together with No. 9 wire as in the case of a fence silo. When a man knows before the material is baled that he is going to use the bales in building a bale silo, he can curve the bales by tying one of the baling wires shorter than the other. Tying one wire 6 or 7 inches shorter will give curves suitable for about a 16-foot silo.

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